POCKET BOOK
OF
Engineering

BY

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C.I.E., M.V.O, C.E., M.I.C.E, M.I.M.E, ETC., ETC.

FIFTH EDITION

REVISED
BY

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THE AUTHOR.

FOREWORD.

When writing his preface on the fifth Edition before departing on his last journey to England with the Royal Commission on Agriculture, little could one imagine that the Author's expectations about the edition of 1906 lasting for his lifetime would after all turn out to be so true. This last effort of his to serve the members of his original profession is, however, in keeping with the gospel of his life-passionate love and incessant work for those with whom he had any common links in life. Full of sorrow at personal bereavement and affliction as I feel in the loss of one whom I revered as my professional father, I commend this last production of his to those who require practical knowledge of engineering details and examples in the readiest and most easily applicable form, with a portrait of the Author to inspire them.

December 5, 1927.

JWALA PRASAD
Chief Engineer, United Provinces,
Public Works Department,
Irrigation Branch.

PREFACE TO THE FIFTH EDITION.

When in 1906, I published a large impression consisting of 13,000 copies of the fourth Edition of my Pocket Book of Engineering, I felt sure that it would last the rest of my life. I therefore left the fifth Edition to take care of itself when the time for it arrived. Contrary to my expectations, however, the Edition was quite exhausted in 1922. I am thankful to merciful Providence to be spared to bring out a revised Edition of my book in spite of my old age and numerous engagements in business and agriculture. In doing so, I have been encouraged by the many kind expressions of appreciation of my labours which I received, from time to time, from those who had used the book and felt benefitted by it, including some laymen who received help in erecting buildings and bridges by referring to the part of the book containing Drawings. I am glad the work is now completed and is ready for the press. I am thankful to Mr. Sohan Lal Bhatia, B. Sc., C. E., Assistant Engineer, whose services I have engaged to edit the work under my instructions and who has spared no pains to make the Pocket Book as complete and acceptable to the profession as possible. I am also indebted to several kind friends who have been good enough to revise the chapters on subjects with which they were specially conversant or otherwise contributed to enhance the usefulness of the book.

My special thanks are due to Mr. A. K. Dutta, the latest authority on Reinforced Brickwork, for contributing a valuable Chapter and Diwan Nanak Chand for revising the Chapters on Mechanical and Electrical Engineering. I am similarly indebted to Rai Bahadur B. P. Verma and Rai Bahadur W. C. Chopra for revising the Chapter on Irrigation. My obligations are also due to Rai Bahadur Ralla Ram, C. I. E., for giving me useful hints on the compilation of the Chapter on Railways. There are numerous other friends to whom my thanks are due for useful informations or practical suggestions. But if I cannot name them all individually here, they should not think that I am unmindful of their contribution to this work.

With the Text and Drawings thus brought up-to-date with the help of many kind friends, I now submit the present Edition to the Engineers and members of Public Works Department as well as such laymen as might seek occasional help and guidance in Engineering and Building.

I have also ventured to add a little information on Agriculture. The time at my disposal did not allow me to make this part as complete as I could have wished, but I hope, that, such as it is, it may be of some service to those who may be thinking of adopting Agriculture as a profession, as I have done after retiring from Government service.

In conclusion, I may be permitted to give a word of advice to young men looking for a career, namely, that Engineering and Agriculture are twin-sisters and that no one can do in one without some knowledge of the other.

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CONTENTS.

PART I.—(Text).

PART II.—(Drawings).

PART I.

TEXT.

Printed at the "Civil and Military Gazette" Press, Lahore

AREA AND POPULATION OF THE PRINCIPAL COUNTRIES.

Country.	Sq. miles.	Population.	Per sq. mile.	Capital.	Population of capital.
Afghanistan ..	246,000	6,000,000	21	Kabul ..	180,000
Albania ..	20,000	1,000,000	50	Tirana ..	12,000
Argentine ..	1,132,000	10,000,000	8	Buenos-Aires ..	1,722,000
Austria ..	31,760	6,100,000	192	Vienna ..	1,842,000
Belgium ..	11,400	7,700,000	658	Brussels ..	808,000
Brazil ..	3,300,000	30,650,000	9	Rio-de-Janerio	1,160,000
Bulgaria ..	40,000	5,000,000	125	Sofia ..	154,000
Canada ..	3,730,000	8,800,000	2	Ottawa ..	108,000
China ..	4,300,000	450,000,000	97	Peking ..	1,300,000
Denmark ..	15,000	3,300,000	220	Copenhagen ..	666,000
Egypt ..	363,181	14,000,000	31	Cairo ..	800,000
England ..	50,874	35,678,300	701	London ..	8,000,000
France ..	213,000	40,000,000	187	Paris ..	3,000,000
Germany ..	182,200	63,000,000	348	Berlin ..	4,000,000
Greece ..	49,000	7,000,000	167	Athens ..	550,000
Hungary ..	36,179	8,000,000	206	Budapest ..	1,200,000
India ..	1,805,000	320,000,000	158	Delhi ..	304,000
Ireland ..	32,586	4,390,000	134	Dublin ..	431,000
Italy ..	120,450	39,000,000	319	Rome ..	692,000
Japan ..	260,800	81,000,000	339	Tokio ..	2,270,000
Mexico ..	769,000	16,000,000	21	Mexico ..	470,000
Newzealand ..	105,000	1,350,000	11	Wellington ..	120,000
Norway ..	125,000	2,700,000	21	Oslo ..	260,000
Persia ..	630,000	10,000,000	16	Teheran ..	210,000
Portugal ..	35,500	6,000,000	155	Lisbon ..	500,000
Russia ..	8,000,000	140,000,000	17	Moscow ..	2,000,000
Scotland ..	30,405	4,882,288	160	Edinburgh ..	420,000
Siam ..	200,000	9,000,000	45	Bangkok ..	450,000
South Africa ..	795,300	8,000,000	10	Pretoria ..	74,000
Spain ..	196,700	21,750,000	110	Madrid ..	750,000
Sweden ..	173,000	6,000,000	34	Stockholm ..	439,000
Switzerland ..	15,950	4,000,000	236	Berne ..	105,000
Tibet ..	500,000	8,000,000	16	Lhassa ..	30,000
Turkey ..	210,000	13,000,000	61	Angora ..	65,000
United States ..	3,027,000	106,000,000	35	Washington ..	440,000
Uraguay ..	72,200	1,700,000	23	Monte-Video ..	450,000
Wales ..	8,466	2,206,712	296	Cardiff ..	200,262
Yugo-slavia ..	87,000	12,000,000	137	Belgrade ..	120,000

AREA AND POPULATION OF BRITISH INDIA AND NATIVE STATES CENSUS OF 1921.

Province State or Agency.	Area in square miles 1921.	Persons.				Difference per cent. 1921 and 1911.
		1921			1911	
		Males.	Females.	Total.	Total.	
Ajmer Merwara ..	2,711	269,566	225,705	495,271	501,395	— 1·2
Andamans and Nicobars ..	3,143	20,793	6,293	27,086	26,459	+ 2·4
Assam	53,015	3,961,109	3,645,121	7,606,230	6,714,299	+ 13·3
Baluchistan	54,228	255,014	165,634	420,648	414,412	+ 1·5
Bengal	76,843	24,151,222	22,544,314	46,695,536	45,482,605	+ 2·7
Behar and Orissa ..	83,161	16,763,866	17,238,323	34,002,189	34,489,544	— 1·4
Bombay Presidency ..	123,621	10,176,969	9,171,250	19,348,219	19,696,266	— 1·8
Burma	233,707	6,756,969	6,455,223	13,212,192	12,115,217	+ 9·1
Central Province and Berar	99,876	6,951,399	6,961,361	13,912,760	13,916,158	..
Coorg	1,582	89,501	74,337	163,638	174,976	— 6·4
Delhi	557	281,633	206,555	488,188	413,447	+ 18·1
Madras	142,260	20,870,749	21,448,236	42,318,985	41,405,404	+ 2·2
North-West Frontier Province.	13,419	1,229,316	1,022,024	2,251,340	2,196,933	+ 2·5
Punjab	99,882	11,306,265	9,378,759	20,685,024	19,578,573	+ 5·7
United Province of Agra and Oudh.	106,295	23,787,745	21,588,042	45,375,787	46,807,490	— 3·1
Total Provinces ..	1,094,300	126,872,116	120,131,177	247,003,293	243,933,178	+ 1·3

Assam States ..	8,456	188,119	195,897	384,016	346,222	+ 10·9
Baluchistan States ..	30,410	205,986	172,991	378,877	420,291	— 9·8
Baroda ..	8,127	1,100,564	1,025,958	2,126,522	2,032,798	+ 4·6
Bengal States ..	5,434	477,143	419,783	896,926	822,565	+ 9·0
Bihar and Orissa States ..	28,648	1,946,186	2,013,483	3,959,669	3,945,209	+ ·0
Bombay States ..	63,453	3,769,962	3,639,467	7,409,429	7,388,051	+ ·3
Central India Agency ..	51,531	3,068,962	2,928,061	5,997,023	6,129,019	— 2·2
Central Provs. States ..	31,176	1,029,398	1,037,502	2,066,900	2,177,152	— 2·4
Gwalior States ..	26,357	1,691,700	1,494,375	3,186,075	3,227,961	— 1·3
Hyderabad States ..	82,698	6,345,071	6,126,699	12,471,770	13,374,676	— 6·8
Kashmir ..	84,258	1,757,122	1,563,396	3,320,518	3,158,126	+ 5·1
Madras States ..	10,696	2,744,921	2,715,391	5,460,312	4,811,841	+ 13·5
Mysore States ..	29,475	3,047,117	2,931,775	5,978,892	5,806,193	+ 3·0
N.-W. F. P. Agencies ..	25,500	1,517,791	1,307,345	2,825,136	1,622,094	+ 74·2
Punjab States ..	37,959	2,425,783	1,990,253	4,416,036	4,212,794	+ 4·8
Rajputana Agency ..	128,987	5,184,891	4,659,493	9,844,384	10,530,432	— 6·5
Sikkim ..	2,818	41,492	40,429	81,721	87,920	— 7·1
U. P. States ..	5,949	581,230	553,051	1,134,881	1,189,874	— 4·6
Total States ..	711,032	37,123,438	34,815,749	71,939,187	71,223,218	+ 1·0
Total India ..	1,805,332	163,995,554	154,946,926	318,942,480	315,156,396	+ 1·2

Population British India =225 per square mile.

Population States =100 per square miles

Thus the area of British India is only 1·5 times greater than the area of states but the population is 3·5 times.

(Whitaker's Almanac 1921).

Months.		0	1	2	3	4	5	6	7	8	9	10	11
January	..	M	Tu	W	Th	Sa	Su	M	Tu	Th	F	Sa	Su
February	..	Th	F	Tu	Su	Tu	W	Th	F	Su	M	Tu	W
March	..	Th	F	Sa	M	Tu	W	Th	Sa	Su	M	Tu	Th
April	..	Su	M	Tu	Th	F	Sa	Su	Tu	W	Th	F	Su
May	..	Tu	W	Th	Sa	Su	M	Tu	Th	F	Sa	Su	Tu
June	..	F	Sa	Su	Tu	W	Th	F	Su	M	Tu	W	F
July	..	Su	M	Tu	Th	F	Sa	Su	Tu	W	Th	F	Su
August	..	W	Th	F	Su	M	Tu	W	F	Sa	Su	M	W
September	..	Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa
October	..	M	Tu	W	F	Sa	Su	M	W	Th	F	Sa	M
November	..	Th	F	Sa	M	Tu	W	Th	Sa	Su	M	Tu	Th
December	..	Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa

Divide the required year by 28. Deduct 1 from remainder for the year before 1900 and 2 for 1900 and after.

Below the balance and against the month named will be the day of the 1st of that month.

Example.—To find day of 1st January 1898, $\frac{1898}{28}$.

Remainder 22, deduct 1 = 22—1 = 21

Below 21 against January is Saturday which is the day of 1st January 1898.

For 1st July 1925, $\frac{1925}{28}$—Remainder 21, deduct 2 = 21—2 = 19, table gives Wednesday.

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Tu	W	Th	F	Su	M	Tu	W	F	Sa	Su	M	W	Th	F	Sa
F	Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa	Su	M	Tu
F	Sa	Su	Tu	W	Th	F	Su	M	Tu	W	F	Sa	Su	M	W
M	Tu	W	F	Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa
W	Th	F	Su	M	Tu	W	F	Sa	Su	M	W	Th	F	Sa	M
Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa	Su	M	Tu	Th
M	Tu	W	F	Sa	Su	M	W	Th	F	Sa	M	Tu	W	Th	Sa
Th	F	Sa	M	Tu	W	Th	Sa	Su	M	Tu	Th	F	Sa	Su	Tu
Su	M	Tu	Th	F	Sa	Su	Tu	W	Th	F	Su	M	Tu	W	F
Tu	W	Th	Sa	Su	M	Tu	Th	F	Sa	Su	Tu	W	Th	F	Su
F	Sa	Su	Tu	W	Th	F	Su	M	Tu	W	F	Sa	Su	M	W
Su	M	Tu	Th	F	Sa	Su	Tu	W	Th	F	Su	M	Tu	W	F

Sizes of Books.

Broadside, folio, quarto (4 to), octavo (8 vo), 12 mo, 16 mo, 32 mo, 48 mo.

Those names indicate the number of pages in the half sheet. For instance an octavo has 8 pages in the half sheet. A crown octavo is about 5″ × 8″.

Weights and Measures.

Measure of Number.

12 units	=	1 dozen.
12 dozens	=	1 gross.
12 gross	=	1 great gross.
20 units	=	1 score (kori).

Writing Paper.

24 Sheets	=	1 quire.
20 Quires	=	1 ream.
10 reams	=	1 bale.

Printing Paper.

480 sheets (English)	=	1 ream.
500 sheets (Indian)	=	1 ream.
2 reams	=	1 bundle.
5 bundles	=	1 bale.

Sizes of Papers [inches.]

Writing and Drawing Paper.

Emperor	.. 72	×	48
Antiquarian	.. 53	×	31
Double Elephant	.. 40	×	26¾
Atlas	.. 34	×	26
Columbier	.. 34½	×	23½
Imperial	.. 30	×	22
Elephant	.. 28	×	23
Super Royal	.. 27	×	19
Royal	.. 24	×	19
Medium	.. 22	×	17½
Large Post	.. 21	×	16½
Copy or Draft	.. 20	×	16
Demy	.. 20	×	15½
Post	.. 19	×	15¼
Foolscap	.. 17	×	13½
Brief	.. 16½	×	13¼
Pott	.. 15	×	12½
Double Imperial	.. 45	×	29
Elephant	.. 34	×	24
Double four pound	.. 31	×	21
Imperial cap	.. 29	×	22
Haven cap	.. 26	×	21
Bag cap	.. 24	×	19½
Kent cap	.. 21	×	18

Brown Paper.

Casing	.. 46	×	36

Printing Paper.

Post	.. 19½	×	15½
Demy	.. 22½	×	17½
Sheet and half Post	.. 23½	×	19½
Medium	.. 24	×	19
Royal	.. 25	×	20
Double Foolscap	.. 27	×	17
Super Royal	.. 27½	×	20½
Double Crown	.. 30	×	20
Imperial	.. 30	×	22
Double Post	.. 31¼	×	19¾
Double Demy	.. 35	×	22½
Double Royal	.. 40	×	25

Tracing Paper and cloth.

Sizes: 19 × 25, 21 × 26, 28 ×40 inches. Also in rolls of 11 and 22 yards.
Parchment Paper—37 and 38 inches wide, in rolls of 20 and 33 yards.
Wall Paper—1 piece of— =36″ × 21″.
Tracing Cloth—widths: 18, 28, 30, 36, 38, 41, 42 inches × 24 yards long.
Continuous cartridge—54 and 60 inches wide.

English Measure.

LENGTH.

12 inches	= 1 foot.
3 feet	= 1 yard.
6 feet	= 1 fathom.
66 feet.	= 1 gunter chain.
	= 4 poles.
220 yards	= 40 poles = 1 furlong.
8 furlongs	= 1 mile.
1 canal mile	= 5000 feet.
3 miles	= 1 league.

SURFACE.

144 sq. inches	= 1 sq. foot.
9 sq. feet	= 1 sq. yard.
30¼ sq. yards	= 1 sq. pole.
40 sq. poles	= 1 rood.
4 roods	= 4840 sq. yds.
	= 1 acre.
640 acres	= 1 sq. mile.
10 square chains [gunter].	= 1 acre.

Cubic Measure.

1728 cubic inches	= 1 cubic foot.
27 cubic feet	= 1 cubic yard.

Measure of Capacity.

4 gills	= 1 pint.
2 pints	= 1 quart.
4 quarts	= 1 gallon.
	= 6 bottles.
2 gallons	= 1 peck.
8 gallons	= 1 bushel.
8 bushels	= 1 quarter.
5 quarters	= 1 load.

One gallon of water	= 10 lbs.
6¼ gallons	= 1 c. ft.
1 c. ft. of water	= 62·5 lbs.
1 bushel	= 1·28 c. ft.
36 bushels	= 1 chaldron.
	= 4½ quarters.
4 gallons	= 1 tin.
	= 24 bottles.

English Standard Weights.

Avoirdupois Weight.

27·344 grains	= 1 Dram.
16 drams	= 1 ounce.
16 ounces	= 7000 grains.
	= 1 pound.
14 lbs.	= 1 stone.
28 lbs.	= 1 quarter.
4 quarters	= 1 hundred weight.
20 hundred weights	= 1 ton
	= 2240 lbs.

Troy Weight.

4 grains	= 1 carat.
6 carats	= 1 penny-weight.
20 pennyweights	= 1 ounce.
12 ounces	= 1 pound.
25 pounds	= 1 quarter.
100 pounds	= 1 cwt.
20 cwt.	= 1 ton.
1 gold carat	= 240 grain
	= 16 mashas.

Apothecaries Weights.

20 grains	= 1 scruple.
3 scruples	= 1 dram.
8 drams	= 1 ounce.
12 ounces	= 1 pound.

The grains, ounces and pounds are the same as in Troy. Medicines are compounded by this weight and the drugs of which they are composed are bought and sold by avoirdupois.

Apothecaries Fluid Measures.

60 minims	= 1 drachm.
60 drops	= 1 drachm=one tea spoonful.
2½ drachms	= 1 dessert spoon.
4 drachms	= 1 table spoonful.
8 drachms	= 1 ounce.
20 ounces	= 1 pint.
2 ounces	= 1 wine glass.
3 ounces	= 1 tea cupful.
8 pints	= 1 gallon.
1 fluid ounce	= 437½ grains.

Sundry Weights.

1 ton of coal	= 44 to 48 c. ft.
1 barrel of tar	= 25 gals.
1 barrel of gunpowder	= 100 lbs.
1 cask of black lead	= 11½ cwt.
1 cord of wood=[4′×4′×8′]	= 128 c. ft.
1 seam of glass	= 120 lb.
1 fagot of steel	= 120 lb.
1 pig of ballast	= 56 lb.
1 barrel of turpentine	= 224 to 280 lbs.
1 sack of wool	= 364 lbs.

1 bale of cotton [Indian]	= 400 to 500 lbs.
1 bale of cotton [U. S. A.]	= 400 to 500 lbs.
1 bag of saltpetre	= 168 lbs.
1 bag of Indian portland cement	= 1·25 c. ft.
1 cubic ft. of unslaked lime [stone]	= 54 lbs.
1 cubic ft. of slaked lime [stone]	= 36 lbs.
1 cubic ft. of slaked lime [kankar]	= 64 lbs.
1 cubic ft of unslaked lime [kankar]	= 74 lbs.

Relation of Capacity and Weight.

1 pint = 1·25 lb.	= 20 ozs.
Gallons × 10	= lb.
Cubic feet × $\frac{100}{16}$	= gallons.
Cubic feet × $\frac{1000}{16}$	= lb.
Gallons × $\frac{16}{100}$	= cubic feet,
lb × $\frac{16}{1000}$	= cubic feet.

Heat or Temperature Scales.

Name of thermometer.	Symbol.	Freezing point.	Boiling point.	Ratio.
Centigrade	C°	0°	100°	$\frac{5}{9}$ [F°—32]
Fahrenheit	F°	32°	212°	$\frac{9}{5}$C°+32
Reaumur	R°	0°	80°	$\frac{4}{9}$ [F°—32]

Note—The normal temperature of the human body is 98 4°F or 37°C or 29·5°R.
Freezing point=32° F, 0° C, 0° R
Boiling point=212° F, 100° C, 80° R.
Absolute temperature is reckoned from absolute Zero, which is at 273° C, below 0°C, 459·4° below 0°F and 218 4° below 0°R.

English Money Measure.

4 farthings	= 1 penny.	5 shillings	= 1 crown
12 pence	= 1 shilling.	20 shillings	= 1 pound.
2 shillings	= 1 florin.	21 shillings	= 1 guinea.

Diameter of ½ penny = 1 inch.

The English Mile compared with other European Measures.

	English Mile.	English Geog. Mile.	French Kilometre.	German Geog. Mile.	Russian Verst.	Austrian Mile.	Dutch Ure.	Norwegian Mile.	Swedish Mile.	Danish Mile.	Swiss Stunde.
English Statute Mile ..	1	0·868	1·609	0·217	1·508	0·212	0·289	0·142	0·151	0·213	0·335
English Geog. Mile ..	1·153	1	1·855	0·250	1·738	0·245	0·333	0·164	0·169	0·246	0·386
Kilometre ..	0·621	0·540	1	0·135	0·937	0·132	0·180	0·088	0·094	0·133	0·208
German Geog. Mile ..	4·610	4·000	17·420	1	6·953	0·978	1·333	0·657	0·694	0·985	1·543
Russian Verst ..	0·663	0·575	1·067	0·144	1	0·141	0·192	0·094	0·100	0·142	0·222
Austrian Mile ..	4·714	4·089	7·586	1·022	7·112	1	1·363	0·672	0·710	1·006	1·578
Dutch Ure ..	3·458	3·000	5·565	0·750	5·215	0·734	1	1·493	0·520	0·738	1·157
Norwegian Mile ..	7·021	6·091	11·299	1·523	10·589	1·489	2·035	1	1·057	1·499	2·350
Swedish Mile ..	6·644	5·764	10·692	1·441	10·019	1·409	1·921	0·948	1	1·419	2·224
Danish Mile ..	4·682	4·062	7·536	1·016	7·078	0·994	1·354	0·667	0·705	1	1·565
Swiss Stunde ..	2·987	2·592	4·808	0·648	4·505	0·634	0·864	0·425	0·449	0·638	1

Indian Weights and Measures.

Indian Cloth Measure.

2¼ inches	= one girrah.
4 girrahs	= one balist.
16 girrahs	= one yard=36 inches

Punjab Land Measure.

9 sq. karm or sirsahi	= 1 marla.
20 marlas	= 1 kanal.
4 kanals	= 1 bigha.
2 bighas	= 1 ghumaon.
1 bigha	= 1620 sq. yards.

United Province Land Measure.

20 Inwansi	= 1 kachwansi.
20 kachwansi	= 1 biswansi.
20 biswansi	= 1 biswa.
20 biswas	= 1 bigha
	= 55×55 sq. yards.
	= 3025 sq. yards.

1 chain = 60 yards [desi].

1 chain × 1 chain = bigha.

Or one bigha = 60×60 sq. yards [ilahi].

= 55×55 = 3025 sq. yards [English].

= $\frac{5}{8}$ acre.

∴ 8 bighas = 5 acres.

Bengal Land Measure.

1 sq. cubit	= 1 ganda.
20 gandas	= 1 chittak.
16 chittaks	= 1 cottah.
20 cottahs	= 1 bigha
1 bigha	= 1600 sq. yards.
121 bighas	= 40 acres.
1936 bighas	= 1 sq. mile.

Madras Land Measure.

144	sq. inches	=	1 sq. ft.
2400	sq. ft.	=	one ground or manai.
24	ground	=	one kani = 1·32 acres (English).
484	kani	=	one sq. mile.
121	kani	=	160 acres.

Bombay Land Measure.

39½	sq. haths	=	1 kathi = 10 sq. yards.
20	kathis	=	1 pand = 200 sq. yards.
20	pands	=	1 bigha = 400 sq. yards.
6	bighas	=	1 rukhey.
20	rukheys	=	1 chhar.

Punjab and U. P. Weights.

8	khash khas	=	1 chawal (rice).
8	chawal	=	1 rati.
8	ratis	=	1 masha.
12	mashas	=	1 tola.
5	tolas	=	1 chittak.
4	chittaks	=	1 pawa.
16	chittaks	=	1 seer.
40	seers	=	1 maund = 82·2857 lbs.
1	standard seer	=	80 tolas.
3	factory maunds	=	2 cwt.
34	factory maunds	=	36 cwt. = 49 bazar maunds.
...	1 cwt.	=	1 maund 14 seer $7\frac{1}{9}$ ch.

MADRAS WEIGHTS.

180	grains	=	1 tola.
3	tolas	=	1 pallum.
8	pallums	=	1 seer.
5	seers	=	1 viss.
8	viss	=	1 md. = 25 lbs.
20	maunds	=	1 candy.

BOMBAY WEIGHTS.

40	seers	=	1 maund.
20	maunds	=	one candy.
1	maund	=	28 lbs.
1	candy	=	5 cwt.

Indian Capacity.

Northern India.

5 seers	= 1 pali.
8 palis	= 1 maund.
1 maund	= 9·81 gallons.

Madras.

12½ olaks	= 1 padi.
8 padis	= 1 markal.
5 markals	= 1 para.
80 paras	= 1 garce.
1 para	=20″×20″×10″.
	=4000 cubic inches.
	=14·43 gallons.

Bombay.

64 seers	= 1 payali.
16 payalis	= 1 para.
8 paras	= 1 candy.
1 para	= 3145 cubic inches
	= 11·34 gallons.

Indian Time Measure.

60 pals	= 1 ghari.
2½ gharis	= 1 hour.
7½ hours	= 1 pohr.
8 pohrs	= 1 day.
7 days	= 1 week.
15 days	= 1 pakh.
30 days	= 1 month.
12 months	= 1 year.
12 years	= 1 jug.
100 years	= 1 century.

English Time Measure.

60 seconds	= 1 minute.
60 minutes	= 1 hour.
24 hours	= 1 day.
7 days	= 1 week.
12 months	= 1 year.
366 days	= 1 leap year

Indian Money Measure.

[Behar, U. P., N. W. F. P. and Punjab.]

2 adhis	= 1 damri.
2 damris	= 1 chadam.
2 chadams	= 1 dhela.
2 dhelas	= 1 pesa.
4 pesas	= 1 anna.
16 annas	= one rupee.

Nautical Measure.

6 feet	= 1 fathom.
126⅔ fathoms	= 1 cable length.
8 cable length	= 1 mile or knot.
3 knots	= 1 league.
20 leagues	= 1 degree.
360 degrees	= 1 earth circumference.

Knots.	Miles.	Knots.	Miles.	Knots.	Miles.
1	1·1515	15	17·2727	29	33·3939
2	2·3030	16	18·4242	30	34·5454
3	3·4545	17	19·5757	31	35·6969
4	4·606	18	20·7272	32	36·8484
5	5·7575	19	21·8787	33	38·0000
6	6·909	20	23·030	34	39·1515
7	8·0606	21	24·1818	35	40·3030
8	9·2121	22	25·3333	36	41·4545
9	10·3636	23	26·4848	37	42·606
10	11·5151	24	27·6363	38	43·7575
11	12·6666	25	28·7878	39	44·909
12	13·8180	26	29·9393	40	46·0606
13	14·9696	27	31·0908	41	47·2121
14	16·1212	28	32·2424	42	48·3636

Metric Measures.

Measure of length ..	**Metre** ..	= 3·2809 ft.
Measure of surface ..	**Are**	= 1076·43 sq. ft. = ·0247 acre.
Measure of volume ..	**Cub. metre Stere** ..	= 35·317 c. ft.
Measure of capacity ..	**Litre**	= ·22009 gals. = 1·76072 pints.
Measure of weight ..	**Gramme**	= ·035 oz. = 15·432349 grs.

Multiples :—	Deca	= 10 times	as Decimetre	= 10 metres.
	Hecto	= 100 ,,	,, Hectare	= 100 ares.
	Kilo	= 1,000 ,,		= 2·471143 acres.
	Myria	= 10,000 ,,		
Sub-multiples :—	Deci	= 1/10 ,,	Decimetre	= 1/10 metre.
	Centi	= 1/100 ,,	,, Centimetre	= 1/100 metre.
	Milli	= 1/1000 ,,		= ·3937 inch.

1 millier or bar = 1,000,000 grams. 1 Quintal = 100,000 grams.

Rough Comparisons. English and Metric Measures.

10 centimetres	= 4 in.	8 kilometres	= 5 miles.
1 litre	= 1¾ pints.	1 cub. metre	= 220 gals.
1 kilogram	= 2¼ lb.	1000 kilograms	= 1 ton.
1 sq. metre	= 10 sq. ft.	1 hectare	= 2½ acres.

Sundry Measures.

Cable length or Cable	.. = 608 ft. = 1/10 Nautical mile.
1 length of cable	.. = 12½ fathoms.
1 palm	.. = 3 inches.
1 hand	.. = 4 inches.

1 cubit	..	..= 18″
1 carat	..	..=3·17 grains.

Carat [gold manufacture] is a measure of fineness. Pure gold is 24 carats. Standard gold is 22 carats.

The gold is called so many carats, say 18 when it contains 18 parts gold and 6 parts alloys.

Measure of Angles.

60″ seconds	..	..= 1 minute.
60′ minutes	..	..= 1 degree.
90 degrees	..	..= 1 quardrant=1 right angle.

Note.—The earth rotates at 15° an hour or 1° in 4 minutes. Consequently the local times of two places having a distance of 1° east or west differs by 4 minutes.

$$\pi = \frac{\text{Circumference}}{\text{Diameter}} = 3{\cdot}14159.$$

Radian is an angle subtended at the centre of a circle by an arc in length to the radius of that circle=57·29580.°

Useful Numbers for Rapid Calculation.

Water.

1 cubic feet of water=62·50 lbs.=·557 cwt.= ·028 tons.

Sea water, specific gravity 1·026; 1 c. ft.=·0285 tons.

Head in feet × ·4325= lbs. per square inch.

lbs. per square inch × 2·3122= Head in feet.

Depth in fathoms × 2·66=lbs. per square inch [Sea water].

Tons of water × 224=gallons; 1 gallon=10 lbs.

Cubic ft. per minute × 9000=gallons per 24 hours.

[Inches diam. of pipe]^2=lbs. of water contained per yard.

Iron and Steel.

1 inch square rod weighs 10 lbs. per yard.

Area × 10= weight per yard in lbs.

A square foot of iron plate, 1 inch thick weighs 40 lbs.

1 cubic inch of cast iron weighs ·26 lbs. wrought iron ·28 lbs.

Horse Power.

Man power × 6 = Horse power [English].
1 H. P. = 33,000 ft. lbs. per minute = 550 ft. lbs. per second.
H. P. of boilers = lbs. of water evaporated per hour ÷ 30.
1 inch water gauges = ·5 lbs. per square inch approx.
1 atmosphere = 14·7 lbs. per square inch = 33·99 ft. of water = 15 lbs.

Rainfall and Snow.

Inches of rainfall × 100·925 = tons per acre.
Inches of rainfall × 14·4686 = millions of gallons per square mile.
weight of snow = ·433 lbs. per square foot for each inch of depth.

Speed.

Feet per minute	×	·01136	= Miles per hour.
Miles per hour	×	88	= Feet per minute.
Feet per minute	×	·00985	= Knots per hour.
Knots per hour	×	101·5228	= Feet per minute.
Feet per second	×	·68182	= Miles per hour.
Feet per second	×	·59142	= Knots per hour.
Miles per hour	×	1·4667	= Feet per second.
Knots per hour	×	1·6909	= Feet per second.

Miscellaneous.

$$H.\ P. = \text{Cusecs} \times H \times \frac{2}{9}$$

$$Q. = \frac{d2}{18}$$

$$H.\ P. = \frac{Q \times F}{15}$$

H. P. = Horse power.
H. = Height to which water is lifted.
Q = Discharge in cusecs.
D. = Bore of pipe in inches. (Centrifugal pipes).
Q. = Discharge in cusecs.
F. = Height of fall in feet.

Note.—Efficiency 50 per cent.

Weight of cast iron pipe per ft. = 10 [Bore × thickness] + Bore

In verandahs the height of arch to the crown

= 1¾ width, *i. e.*, H = 1¾ L.

Where L = width of verandah.

One waggon load, *i.e.*, 20 tons of coal is required to burn one lakh of 9″ bricks in the Bull type kiln.

Ready Reckoner for timber logs per foot length.

Girth feet.	Cubic Contents per running foot for											
	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
2	·250	·2712	·2933	·3164	·3402	·3650	·3906	·417	·444	·4727	·5017	·5317
3	·562	·5941	·6268	·6683	·6944	·7296	·7656	·8025	·8402	·8789	·9183	·9588
4	1·00	1·0424	1·0857	1·1289	1·173	1·2188	1·266	1·3132	1·3596	1·410	1·459	1·511
5	1·562	1·615	1·669	1·723	1·777	1·834	1·890	1·949	2·005	2·066	2·126	2·188
6	2·250	2·312	2·376	2·441	2·506	2·572	2·640	2·708	2·777	2·848	2·988	2·99
7	3·062	3·14	3·201	3·285	3·360	3·438	3·516	3·595	3·673	3·754	3·834	3·917
8	4·000	4·083	4·168	4·259	4·340	4·427	4·515	4·604	4·694	4·785	4·876	4·968
9	5·062	5·156	5·251	5·347	5·444	5·542	5·640	5·734	5·84	5·918	6·043	6·146
10	6·250	6·354	6·46	6·566	6·673	6·701	6·890	7·00	7·1110	7·223	7·335	7·448
11	7·562	7·677	7·793	7·91	8·027	8·145	8·265	8·355	8·5065	8·628	8·751	8·875
12	9·00	9·125	9·251	9·378	9·506	9·635	9·766	9·897	10·04	10·16	10·293	10·043
13	10·562	10·698	10·84	10·972	11·11	11·250	11·38	11·53	11·678	11·826	11·960	12·104
14	12·25	12·396	12·54	12·69	12·84	12·99	13·11	13·29	13·44	13·59	13·75	13·90
15	14·062	14·219	14·376	14·535	14·694	14·854	15·015	15·177	15·34	15·503	15·66	15·83
16	16·000	16·166	16·33	16·50	16·67	16·84	17·015	17·187	17·36	17·53	17·71	17·88
17	18·062	18·24	18·42	18·6	18·78	18·96	19·14	19·32	19·51	19·69	19·88	20·06
18	20·25	20·44	20·63	20·82	21·01	21·2	21·39	21·58	21·78	21·97	22·17	22·37

The following formula has been used in calculating the above table :—Cubic contents $= \left(\frac{\text{Mean girth}}{4}\right)^2 \times \text{length}$

If the wood in question is tapering from one end to the other it should be measured in the middle. In case it is irregular take dimensions at two or three places.

Example.—Find the cubic contents of a log 32′-10″ long and having a girth of 16′-5″.

Table gives 16·84 for 16′-5″ which is contents of 1 foot long.

Total cubic contents =32′10″× 16·84 =553 cubic feet say

Table of Compound Conversion Factors.

To reduce.	Into.	Multiplier.	Reciprocal.
Cubic feet per second ..	Cubic metres per hour	101·94	·0098
Feet per second ..	Centimetres per second	30·479	·0328
Pounds per lineal foot ..	Kilos per lineal metre	1·488	·672
Pounds per lineal yard ..	Kilos per lineal metre ..	·496	2·016
Tons per lineal foot ..	Kilos per lineal metre ..	3333·3	·0003
Pounds per square inch ..	Kilos per square Centimetre ..	·0703	14·223
Tons per square inch ..	Kilos per square Milimetre ..	1·575	·635
Pounds per square foot ..	Kilos per square metre ..	4·84	·2048
Tons per square foot ..	Tonnes per square metre. ..	10·936	·0914
Pounds per cubic foot ..	Kilos per cubic metre ..	15·89	·0624
Pounds per cubic yard ..	Kilos per cubic metre ..	·5933	1·685
Tons per cubic yard ..	Tonnes per cubic metre ..	1·329	·752
Grains per gallon ..	Grammes per litre ..	·01426	70·153
Pounds per gallon ..	Kilos per litre ..	·0998	10·02
Gallons per square foot ..	Litres per square metre	48·93	·0204
Foot-pounds ..	Kilogram-metres ..	·1382	7·233
Foot-tons ..	Tonne-metres ..	·3	3·28
Horse-power ..	Force-de-cheval ..	1·0139	·9863
Pounds per horse-power ..	Kilos per cheval ..	·447	2·235
Cubic feet per second ..	Gallons per minute ..	374·4	·00267
Acres ..	Square metre ..	4046·7	·00024
Acres ..	Square miles ..	·0015	·640
Acres ..	Square feet ..	43560	·000023
Pounds ..	Kilogram ..	·45	2·2
Miles per hour ..	Kilometres per hour ..	1·6	·625
Miles per hour ..	Metres per second ..	·447	2·237
Feet ..	Metres ..	·3	3·28
Grains ..	Grammes ..	·065	15·44
Tons per square yard ..	Tonnes per square metre	1·195	·836

READY RECKONER FOR SAWN SCANTLINGS PER FOOT RUN.

In.	¼″	½″	¾″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″
¼	·00	·00	·00	·00	·00	·00	·01	·01	·01	·01	·01	·02	·02	·02	·02	·02	·02	·03
½	·00	·00	·00	·00	·01	·01	·01	·02	·02	·02	·03	·03	·03	·04	·04	·04	·05	·05
¾	·00	·00	·00	·00	·01	·02	·02	·03	·03	·04	·04	·05	·05	·06	·06	·07	·07	·08
1	·00	·00	·00	·01	·01	·02	·03	·03	·04	·05	·06	·06	·07	·08	·08	·09	·10	·10
¼	·00	·01	·01	·01	·02	·03	·03	·04	·05	·05	·06	·07	·08	·09	·09	·11	·12	·12
½	·00	·01	·01	·01	·02	·03	·04	·05	·06	·07	·08	·09	·10	·11	·12	·13	·14	·15
¾	·00	·01	·01	·01	·02	·04	·05	·06	·07	·08	·10	·11	·12	·13	·15	·16	·17	·18
2	·00	·01	·01	·01	·03	·04	·06	·07	·08	·10	·11	·13	·14	·15	·17	·18	·19	·21
¼	·00	·01	·01	·01	·03	·05	·07	·08	·09	·11	·12	·14	·16	·17	·19	·20	·22	·23
½	·00	·01	·01	·01	·03	·05	·07	·09	·10	·12	·14	·16	.17	·19	·21	·22	·24	·25
¾	·00	·01	·01	·02	·04	·06	·08	·09	·11	·13	·15	·17	·19	·21	·23	·25	·27	·28
3	·00	·01	·02	·02	·04	·06	·08	·10	·13	·15	·17	·19	·21	·23	·25	·27	·29	·31
¼	·00	·01	·02	·02	·04	·07	·10	·11	·14	·16	·18	·20	·22	·25	·27	·29	·31	·33
½	·01	·01	·02	·02	·05	·08	·10	·12	·15	·17	·19	·22	·24	·27	·29	·31	·34	·36
¾	·01	·01	·02	·03	·05	·08	·10	·13	·16	·18	·21	·23	.26	·29	·31	·34	·36	·39
4	·01	·01	·02	·03	·06	·08	·11	·14	·17	·20	·22	·25	·28	·31	·33	·36	·39	·42
¼	·01	·01	·02	·03	·06	·09	·12	·15	·18	·21	·23	·26	·29	·32	·35	·38	·41	·44
½	·01	·02	·02	·03	·07	·10	·13	·16	·19	·22	·25	·28	·31	·34	·37	·40	·43	·46
¾	·01	·02	·02	·03	·07	·10	·13	·16	·20	·23	·26	·30	·33	·36	·40	·43	·46	·49
5	·01	·02	·03	·03	·07	·10	·14	·17	·21	·24	·28	·31	·35	·38	·42	·45	·48	·52
¼	·01	·02	·03	·04	·07	·11	·15	·18	·22	·25	·29	·33	·36	·40	·44	·47	·51	·54
½	·01	·02	·03	·04	·08	·12	·15	·19	·23	·27	·30	·34	·38	·42	·46	·49	·53	·56
¾	·01	·02	·03	·04	·08	·12	·16	·20	·24	·28	·32	·36	·40	·44	·48	·52	·56	·59
6	·01	·02	·03	·04	·08	·12	·17	·21	·25	·29	·33	·38	·42	·46	·50	·54	·59	·63
¼	·01	·02	·03	·04	·09	·13	·17	·22	·26	·30	·35	·39	·43	·48	·52	·56	·61	·64
½	·01	·02	·03	·04	·09	·13	·18	·23	·27	·31	·36	·40	·45	·49	·54	·58	·63	·67
¾	·01	·02	·04	·05	·09	·14	·19	·23	·28	·33	·37	·42	·47	·50	·56	·61	·66	·70
7	·01	·02	·04	·05	·10	·15	·20	·25	·29	·34	·39	·44	·49	·54	·58	63	·68	·73
¼	·01	·02	·04	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75
½	·01	·03	·04	·05	·10	·16	·21	·26	·31	·36	·42	·47	·52	·57	·62	·67	·72	·77
¾	·01	·03	·04	·05	·11	·16	·22	·27	·32	·38	·43	·48	·54	·59	·65	·70	·76	·80
8	·01	·03	·04	·05	·11	·17	·22	·28	·33	·39	·44	·50	·55	·61	·67	·72	·78	·83

In.	¼"	½"	¾"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"
¼	·01	·03	·04	·06	·12	·17	·23	·29	·34	·40	·46	·52	·57	·63	·69	·75	·81	·85
¾	·01	·03	·04	·06	·12	·18	·24	·30	·35	·41	·47	·53	·59	·65	·71	·77	·83	·88
½	·01	·03	·05	·06	·12	·18	·24	·30	·36	·42	·49	·55	·61	·67	·73	·79	·85	·91
9	·01	·03	·05	·06	·13	·19	·25	·31	·37	·44	·50	·56	·62	·69	·75	·81	·88	·94
¼	·02	·03	·05	·06	·13	·19	·26	·32	·38	·45	·51	·58	·64	·71	·77	·83	·90	·96
½	·02	·03	·05	·06	·13	·20	·26	·33	·40	·46	·53	·59	·66	·73	·79	·85	·92	·98
¾	·02	·03	·05	·07	·14	·20	·27	·34	·41	·47	·54	·61	·68	·74	·81	·88	·95	1·01
10	·02	·03	·05	·07	·14	·21	·28	·35	·42	·48	·55	·62	·69	·76	·83	·90	·97	1·04
¼	·02	·04	·05	·07	·14	·21	·28	·36	·43	·49	·57	·64	·71	·78	·85	·92	·99	1·06
½	·02	·04	·05	·07	·15	·22	·29	·36	·44	·50	·58	·66	·73	·80	·87	·94	1·02	1·09
¾	·02	·04	·06	·07	·15	·22	·30	·37	·45	·51	·60	·67	·75	·82	·90	·97	1·05	1·12
11	·02	·04	·06	·08	·15	·23	·31	·38	·46	·53	·61	·69	·76	·84	·92	1·00	1·07	1·15
¼	·02	·04	·06	·08	·16	·23	·31	·39	·47	·53	·62	·70	·78	·86	·94	1·02	1·10	1·17
½	·02	·04	·06	·08	·16	·24	·32	·40	·48	·55	·64	·72	·80	·88	·96	1·04	1·12	1·19
¾	·02	·04	·06	·08	·16	·24	·33	·41	·49	·56	·65	·73	·81	·90	·98	1·06	1·14	1·22
12	·02	·04	·06	·08	·17	·25	·33	·42	·50	·58	·67	·75	·83	·92	1·00	1·08	1·17	1·25
¼	·02	·04	·06	·08	·17	·25	·34	·43	·51	·59	·68	·76	·85	·94	1·02	1·10	1·19	1·29
½	·02	·05	·06	·08	·18	·26	·34	·44	·52	·60	·70	·78	·86	·96	1·04	1·12	1·22	1·27
¾	·02	·05	·07	·08	·18	·27	·35	·45	·53	·62	·71	·80	·88	·98	1·06	1·14	1·24	1·32
13	·02	·05	·07	·09	·18	·27	·36	·45	·55	·63	·72	·81	·90	1·00	1·08	1·17	1·26	1·35
¼	·02	·05	·07	·09	·19	·28	·36	·46	·55	·64	·74	·83	·92	1·01	1·10	1·19	1·29	1·37
½	·02	·05	·07	·09	·19	·28	·37	·47	·56	·65	·75	·85	·93	1·03	1·12	1·21	1·31	1·40
¾	·02	·05	·07	·10	·19	·29	·38	·48	·57	·66	·77	·86	·95	1·05	1·15	1·25	1·34	1·43
14	·02	·05	·07	·10	·19	·29	·39	·49	·58	·67	·77	·87	·98	1·07	1·17	1·27	1·36	1·46
¼	·02	·05	·08	·10	·20	·30	·39	·49	·59	·69	·79	·89	·99	1·09	1·19	1·29	1·38	1·48
½	·02	·05	·08	·10	·20	·30	·40	·50	·60	·70	·80	·90	1·00	1·10	1·20	1·31	1·41	1·52
¾	·02	·05	·08	·10	·20	·31	·41	·51	·61	·71	·82	·92	1·02	1·12	1·22	1·33	1·45	1·53
15	·03	·06	·08	·10	·21	·31	·42	·52	·62	·73	·83	·94	1·04	1·15	1·25	1·35	1·46	1·56
¼	·03	·06	·08	·11	·21	·31	·42	·52	·63	·74	·85	·96	1·06	1·17	1·27	1·37	1·48	1·58
½	·03	·06	·80	·11	·22	·32	·43	·53	·64	·75	·86	·98	1·08	1·19	1·29	1·39	1·50	1·61
¾	·03	·06	·08	·11	·22	·32	·43	·54	·65	·77	·88	·99	1·09	1·20	1·31	1·41	1·53	1·64
6	·03	·06	·08	·11	·22	·33	·44	·55	·67	·78	·89	1·00	1·11	1·22	1·33	1·44	1·56	1·67
¼	·03	·06	·09	·12	·23	·33	·44	·56	·68	·80	·91	1·01	1·13	1·24	1·35	1·46	1·58	1·69
½	·03	·06	·09	·12	·23	·34	·45	·57	·69	·81	·92	1·02	1·15	1·26	1·37	1·48	1·60	1·71
¾	·03	·06	·09	·12	·24	·35	·46	·58	·70	·82	·93	1·04	1·17	1·28	1·39	1·50	1·62	1·74
7	·03	·06	·09	·12	·24	·35	·47	·59	·71	·83	·94	1·06	1·18	1·30	1·42	1·53	1·65	1·77

Ready Reckoner for Sawn Scantlings per foot run—(concluded.)

In.	¼"	½"	¾"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"
¼	03	·06	·09	·12	·24	·35	·47		·72	·85	·97	1·08	1	·32	1·44	·55	1·69	1·79
½	03	·06	·09	·12	·25	·36	·48		·73	·86	·98	1·09	1	34	1·46	1·57	1·70	1·82
¾	·03	·06	·09	·12	·25	·37	·49		·74	·87	·99	1	24	1·36	1·48	1·59	1·73	1·85
18	·03	·06	·09	·12	·25	·38	·50		·75	·88	1·00		25	1 38	1·50	·62	1·75	1·88
8¼	·03	·06	·09	·13	·25	·38	·51		·76	·89	1·02	·13	1 26	1·40	1·52	1·65	1·77	1·90
½	·03	·07	·10	·13	·25	·38	·52		·77	·90	1·03	·15	28	1·41	1·54	1·67	1·79	1·92
¾	·03	·07	·10	·13	·26	·39	·53		·78	·91	1·04	·17	30	1·43	1·56	1·69	1·82	1·95
19	·03	·07	·10	·13	·26	·40	·53		·79	·92	1·06	19	1 ·32	1·45	1·58	1·72	1·85	1·98
¼	·03	·07	·10	·13	·26	·40	·54		80	·93	·07	.21	1·34	1·47	1 60	1·74	1 87	2·00
½	·03	·07	·10	·13	·27	·41	·54		·81	·94	·08	·22	1·36	1·49	1·62	·76	1·89	2·03
¾	·03	·07	·10	·13	·27	·42	·56	68	·82	·95	·10	24	1·38	1·51	1·66	1·79	1·92	2·06
20	·03	·07	·10	·14	·28	·42	·56	69	·83	·97	·11	1·25	1·39	53	1·67	1·81	1·94	2·08
21	·04	·08	·11	·15	·29	·44	·58	·73	·87	1·02	1·17	1·31	1·46	1·60	1 75	1·91	2·03	2 19
22	·04	·08	·11	·15	·31	·46	·60	·76	·92	1·07	1·22	1·38	1	·68	1 83	1·99	2·14	2·30
23	·04	·08	·12	·16	·32	·48	·64	·80	·96	1·12	1·24	1·45		1·75	1·92	2·08	2·24	2·40
24	·04	·08	·13	·17	·33	·50	·67	·83	1·00	1·17	1·33	1·50	1·67	1·83	2·00	2·17	2·33	2·50

NOTE.—To find contents of any length, multiply the length required by the contents obtainable from this table.

Example.—Find the cubic contents of 10" × 5" beam 10 feet long. From the table we find ·35 against 10" × 5".

∴ For length of one foot = ·35 c. ft.

∴ For length of 10 feet = 3·5 c. ft.

(*ii*) A beam is 17½ ft. long and 9½" × 15½" in section. Find its cubic contents.

From the table we find 2·03 against 19½" × 15".

Add ·07 found against 19½" × ½".

∴ Cubic contents per ft. run = 2·03 + ·07

= 2·1

∴ Cubic contents of 17½ ft. = 2·1 × 17½.

= 36·75 c. ft.

Square of Lyallpur district = 1100′ × 1100′ = 27·7 acres.

Rectangle of Montgomery district = 1100′ × 990′ = 25 acres.

If X = number of acres,

then number of squares $= \frac{X \times 36}{100}$

and No. of Rectangles $= \frac{X \times 40}{100}$

One killa in Lyallpur district = 220′ × 220′.

One killa in Montgomery district = 220′ × 198′.

Table for converting inches into Decimals of a foot.

In.	¼	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4
Ft.	·021	·042	·062	·083	·104	·125	·146	·167	·187	·208	·229	·250	·271	·292	·312	·333
In.	4¼	4½	4¾	5	5¼	5½	5¾	6	6¼	6½	6¾	7	7¼	7½	7¾	8
Ft,	·354	·375	·396	·417	·437	·458	·479	·500	·521	·542	·562	·583	·604	·625	·646	·667
In.	8¼	8½	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾	11	11¼	11½	11¾	12
Ft.	·687	·708	·729	·750	·771	·792	·812	·833	·854	·875	·896	·917	·937	·958	·979	1·00

Table of Squares, Cubes, Square roots and Cube roots.

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root	Cube root.
1	1	1	1·00000	1·0000	21	441	9261	4·58258	2·7589
2	4	8	1·41421	1·2599	22	484	10648	4·69042	2·8020
3	9	27	1·73205	1·4422	23	529	12167	4·79583	2·8439
4	16	64	2·00000	1·5874	24	576	13824	4·89898	2·8845
5	25	125	2·23607	1·7100	25	625	16625	5·00000	2·9240
6	36	216	2·44949	1·8171	26	676	17576	5·09902	2·9625
7	49	343	2·64575	1·9129	27	729	19683	5·19615	3·0000
8	64	512	2·82843	2·0000	28	784	21952	5·29150	3·0366
9	81	729	3·00000	2·0801	29	841	24389	5·38516	3·0723
10	100	1000	3·16228	2·1544	30	900	27000	5·47723	3·1072
11	121	1331	3·31662	2·2240	31	961	29791	5·56776	3·1414
12	144	1728	3·46410	2·2894	32	1024	32768	5·65685	3·1748
13	169	2197	3·60555	2·3513	33	1089	35937	5·74456	3·2075
14	196	2744	3·74166	2·4101	34	1156	39304	5·83095	3·2396
15	225	3375	3·87298	2·4662	35	1225	42875	5·91609	3·2711
16	256	4096	4·00000	2·5198	36	1296	46656	6·00000	3·3019
17	289	4913	4·12311	2·5713	37	1369	50653	6·08276	3·3322
18	324	5832	4·24264	2·6207	38	1444	54872	6·16441	3·3620
19	361	6859	4·35890	2·6684	39	1521	59319	6·24500	3·3912
20	400	8000	4·47214	2·7144	40	1600	64000	6·32456	3·4200

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
41	1681	68921	6·40312	3·4482		6561	531341	9·0000(	4·3267
42	1764	74088	6·48074	3·4760	82	6724	551368	9·0553	4·3445
43	1849	79507	6·55744	3·5034	83	6889	571787	9·1104	4·3621
44	1936	85184	6·6332	3·5303	84	7056	592704	9·16515	4·3795
45	2025	91125	6·7082(	3·5569	85	7225	614125	9·21954	4 3998
46	2116	97336	6·78233	3·5830	86	7396	636056	9·27362	4·4140
47	2209	103823	6·85565	3·6088	87	7569	658503	9·32738	4·4310
48	2304	110592	6·92820	3·634	88	7744	681472		4·4480
49	2401	117649	7·00000	3·6593	89	7921	704969	9·43398	4·4647
50	2500	125000	7·07107	3·6840	90	8100	729000	9·48683	4·4814
51	2601	132651	7·1414	3·7084	91	8281	753571	9·53939	4 4979
52	2704	140608	7·2111	3·7325	92	8464	778688	9·59166	4·5144
53	2809	148877	7·28011	3·7563	93	8649	80435	9·64365	4·5307
54	2916	157464	7·34807	3·7798	94	8836	830584	9·69536	4·5468
55	3025	166375	7·41620	3·8030	95	9025	85737	9·74679	4·5629
56	3136	175616	7·48331	8259	96	9216	884736	9·79796	4·5789
57	3249	185193	7·54983	3 8485	97	9409	912673	9·84886	4·5947
58	3364	195112	7·61577	3·8709	98	9604	94119	9·89949	6104
59	3481	205379	7·68115	8930	99	9801	970299	9·94987	6261
60	3600	216000	7·74597	3·9149	100	10000	1000000	10·0000	4·6416
61	3721	226981	7·81025	3·9365	101	10210	1030301	10·04988	4·6570
62	3844	238328	7·87401	3·9579	102	10404	1061208	10·09950	4·6723
63	3969	250047	7·93725	·9791	103	10609	1C9272	10·14889	4·6875
64	4096	262144	8·00000	4·0000	104	10816	1124864	10·19804	7027
65	4225	274625	8·06226	4·0207	105	11025	1157625	10·24695	7177
66	4356	287496	8·12404	4·0412	106	11236	1191016	10·29563	·7326
67	4489	300763	8·18535	4·0615	107	11449	1225043	10·34408	4·7475
68	4624	314432	8·24621	4·0817	108	11664	1259712	10·39230	·7622
69	4761	328509	8·30662	4·1016	109	11881	1295029	10·44031	·7769
70	4900	343000	8·36660	4·1213	110	12100	1331000	0·48809	4·7814
71	5041	357911	8·42615	4·1408	111	12321	1367631	0·53565	4 8059
72	5184	373248	8·48528	4·1602	112	12544	1404928	0·58301	4 8203
73	5329	389017	8·54400	·1793	113	12769	1442897	0·63015	4 8346
74	5476	405224	8·60233	4·1983	114	12996	1481544	0·67708	4 8438
75	5625	421875	8·66025	4·2172	115	13225	1520875	0·72381	4·8629
76	5776	438976	8·71780	4·2358	116	13456	1560896	77033	4·8770
77	5929	456533	8·77496	4·2543	117	13689	1601613	81665	4·8910
78	6084	474552	8·83176	·2727	118	13924	1643032	86278	4·9049
79	6241	493039	8·888	4·2908	119	14161	1685159	90871	4·9186
80	6400	512000	8·94427	4·3089	120	14400	1728000	95445	4·9324

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
121	14641	1771561	11·00000	4·9461	161	25921	4173281	12·68858	5·4401
122	14884	1815848	11·04536	4·9597	162	26244	4251528	12·72792	5·4514
123	15129	1860867	11·09054	4·9732	163	26569	4330747	12·76715	5·4626
124	15376	1906624	11·13558	4·9866	164	26896	4410944	12·80625	5·4737
125	15625	1953125	11·18034	5·0000	165	27225	4492125	12·84523	5·4848
126	15876	2000376	11·22497	5·0133	166	27556	4574296	12·88410	5·4959
127	16129	2048383	11·26943	5·0265	167	27889	4657463	12·92285	5·5069
128	16384	2097152	11·31371	5·0397	168	28224	4741633	12·96148	5·5178
129	16641	2146689	11·35782	5·0523	169	28561	4826809	13·00000	5·5288
130	16900	2197000	11·40178	5·0658	170	28900	4913000	13·03840	5·5397
131	17161	2248091	11·44552	5·0788	171	29241	5000211	13·07670	5·5505
132	17424	2299968	11·48913	5·0916	172	29584	5088448	13·11488	5·5613
133	17689	2352637	11·53256	5·1045	173	29929	5177717	13·15295	5·5721
134	17956	2406104	11·57584	5·1172	174	30276	5268024	13·19091	6·5828
135	18225	2460375	11·61895	5·1299	175	30625	5359375	13·22876	5·5934
136	18496	2515456	11·66190	5·1426	176	30976	5451776	13·26650	5·6041
137	18769	2571353	11·70470	5·1551	177	31329	5545233	13·30413	5·6147
138	19044	2628072	11·74734	5·1676	178	31684	5639752	13·34166	5·6252
139	19321	2685619	11·78983	5·1801	179	32041	5735339	13·37909	5·6357
140	19600	2744000	11·83220	5·1925	180	32400	5832000	13·41641	5·6462
141	19881	2803221	11·87434	5·2048	181	32761	5929741	13·45362	5·6567
142	20164	2863288	11·91640	5·2171	182	33124	6028568	13·49074	5·6671
143	20449	2924207	11·95830	5·2293	183	33489	6128487	13·52775	5·6774
144	20736	2985984	12·00000	5·2415	184	33856	6229504	13·56466	5·6877
145	21025	3048625	12·04159	5·2536	185	34225	6331625	13·60147	5·6980
146	21316	3112136	12·08305	5·2656	186	34596	6434856	13·63818	5·7083
147	21609	3176523	12·12436	5·2776	187	34969	6539203	13·67479	5·7185
148	21904	3241792	12·16555	5·2896	188	35344	6644672	13·71136	5·7287
149	22201	3307949	12·20656	5·3015	189	35721	6751269	13·74753	5·7388
150	22500	3375000	12·24745	5·3133	190	36100	6859000	13·78405	5·7489
151	22801	3442951	12·28821	5·3251	191	36481	6967871	13·82028	5·7590
152	23104	3511808	12·32883	5·3368	192	36864	7077888	13·85641	5·7690
153	23409	3581577	12·36932	5·3485	193	37249	7189057	13·89244	5·7790
154	23716	3652264	12·40967	5·3601	194	37636	7301384	13·92839	5·7890
155	24025	3723875	12·44990	5·3717	195	38025	7414875	13·96424	5·7989
156	24336	3796416	12·49000	5·3832	196	38416	7529536	14·00000	5·8088
157	24649	3869893	12·52996	5·3947	197	38809	7645373	14·03567	5·8186
158	26964	3944312	12·56981	5·4061	198	39204	7762392	14·07126	5·8285
159	25281	4019679	12·60952	5·4[illegible]75	199	39601	7880599	14·16674	5·8383
160	25600	4096000	12·64911	5·4288	200	40000	8000000	14·14214	5·8480

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
201	40401	8120601	14·1774	5·8578	241	58081	13997521	15·5242	6·2231
202	40804	8242408	14·2127	5·8675	242	58564	14172488	15·5563	6·2317
203	41209	8365427	14·2478	5·8771	243	59049	14348907	15·5885	6·2403
204	41616	8489664	14·2829	5·8868	244	59536	14526784	15·6205	6·2488
205	42025	8615125	14·3178	5·8964	245	60025	14706125	15·6525	6·2573
206	42436	8741816	14·3527	5·9059	246	60516	14886936	15·6844	6·2658
207	42849	8869743	14·3875	5·9155	247	61009	15069223	15·7162	6·2743
208	43264	8998912	14·4222	5·9250	248	61504	15252992	15·7480	6·2828
209	43681	9129329	14·4568	5·9345	249	62001	15438249	15·7797	6·2912
210	44100	9261000	14·4914	5·9439	250	62500	15625000	15·8114	6·2996
211	44521	9393931	14·5258	5·9533	251	63001	15813251	15·8430	6·3080
212	44944	9528128	14·5602	5·9627	252	63504	16003008	15·8745	6·3164
213	45369	9663597	14·5945	5·9721	253	64009	16194277	15·9060	6·3247
214	45796	9800344	14·6287	5·9814	254	64516	16387064	15·9374	6·3330
215	46225	9933875	14·6629	5·9907	255	65025	16581375	15·9687	6·3413
216	46656	10077696	14·6969	6·0000	256	65536	16777216	16·0000	6·3496
217	47089	10218313	14·7309	6·0092	257	66049	16974593	16·0312	6·3579
218	47524	10360232	14·7648	6·0185	258	66564	17173512	16·0624	6·3661
219	47961	10503459	14·7986	6·0277	259	67081	17373979	16·0935	6·3743
220	48400	10648000	14·8324	6·0368	260	67600	17576000	16·1245	6·3825
221	48841	10793861	14·8661	6·0459	261	68121	17779581	16·1555	6·3907
222	49284	10941048	14·8997	6·0550	262	68644	17984728	16·1864	6·3988
223	49729	11089567	14·9332	6·0641	263	69169	18191447	16·2172	6·4070
224	50176	11239424	14·9666	6·0732	264	69696	18399744	16·2481	6·4151
225	50625	11390625	15·0000	6·0822	265	70225	18609625	16·2788	6·4232
226	51076	11543176	15·0333	6·0912	266	70756	18821096	16·3095	6·4312
227	51529	11697083	15·0665	6·1002	267	71289	19034163	16·3401	6·4393
228	51984	11852352	15·0997	6·1091	268	71824	19248832	16·3707	6·4473
229	52441	12008989	15·1327	6·1180	269	72361	19465109	16·4012	6·4553
230	52900	12167000	15·1658	6·1269	270	72900	19683000	16·4317	6·4633
231	53361	12326391	15·1987	6·1358	271	73441	19902511	16·4621	6·4713
232	53824	12487168	15·2315	6·1445	272	73984	20123648	16·4924	6·4792
233	54289	12649387	15·2643	6·1534	273	74529	20346417	16·5227	6·4872
234	54756	12812904	15·2971	6·1622	274	75076	20570824	16·5529	6·4951
235	55225	12977875	15·3297	6·1710	275	75625	20796875	17·5831	6·5030
236	55696	13144256	15·3623	6·1797	276	76176	21024576	16·6132	6·5108
237	56169	13312053	15·3948	6·1885	277	76729	21253933	16·6433	6·5187
238	56644	13481272	15·4272	6·1972	278	77284	21484952	16·6733	6·5265
239	57121	13651919	15·4596	6·2058	279	77841	21717639	16·7033	6·5343
240	57600	13824000	15·4919	6·2145	280	78400	21952000	16·7332	6·5421

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	
281	78981	22188041	16·7631	6·5499	321	103041	33076161	17·9165	
282	79524	22425768	16·7929	6·5577	322	103684	33386248	17·9444	
283	80089	22665187	16·8226	6·5654	323	104329	33698267	17·9722	
284	80656	22906304	16·8523	6·5731	324	104976	34012224	18·0000	6·868
285	81225	23149125	16·8819	6·5808	325	105625	34328125	18·0278	6·875
286	81796	23393656	16·9115	6·5885	326	106276	34645976	18·0555	
287	82369	23639903	16·9411	6·5962	327	106929	34965783	18·0831	
288	82944	23887872	16·9700	6·6039	328	107584	35287552	18·1108	
289	83521	24137569	17·0000	6·6110	329	108241	35611289	18·1384	
290	84100	24389000	17·0294	6·6190	330	108900	35937000	18·1659	
291	84681	24642171	17·0587	6·6270	331	109561	36264691	18·1934	
292	85264	24897088	17·0880	6·6340	332	110224	36594368	18·2209	
293	85849	25153757	17·1172	6·6420	333	110889	36926037	18·2483	
294	86436	25412184	17·1464	6·6490	334	111556	37259704	18·275	
295	87025	25672375	17·1756	6·6570	335	112225	37595375	18·3030	
296	87616	25934336	17·2047	6·6640	336	112896	37933056	18·3303	
297	88209	26198073	17·2337	6·6720	337	113569	38272753	18·3576	
298	88804	26463592	17·2627	6·6790	338	114244	38614472	18·3848	
299	89401	26730899	17·2917	6·6870	339	114921	38958219	18·4120	
300	90000	27000000	17·3205	6·6940	340	115600	39304000	18·4391	
301	90601	27270901	17·3494	6·7020	341	116281	39651821	18·4662	
302	91204	27543608	17·3781	6·7090	342	116964	40001688	18·4932	
303	91809	27818127	17·4069	6·7170	343	117649	40353607	18·5203	
304	92416	28094464	17·4356	6·7240	344	118336	40707584	18 5472	
305	93025	28372625	17·4642	6·7310	345	119025	41063625	18·5742	
306	93636	28652616	17·4929	6·7390	346	119716	41421736	18·6011	
307	94249	28934443	17·5214	6·7460	347	120409	41781923	18·6279	
308	94864	29218112	17 5499	6·7530	348	121104	42144192	18·6548	
309	95481	29503629	17·5784	6·7610	349	121801	42508549	18·6815	
310	96100	29791000	17·6068	6·7680	350	122500	42875000	18·7083	
311	96721	30080231	17·6352	6·7750	351	123201	43243551	18·7350	
312	97344	30371328	17·6635	6·7820	352	123904	43614208	18·7617	
313	97969	30664297	17·6918	6·7900	353	124609	43986977	18·7883	
314	98596	30959144	17·7200	6·7970	354	125316	44361864	18·8149	
315	99225	31255875	17·7482	6·8040	355	126025	44738875	18·8414	
316	99856	31554496	17·7764	6·8110	356	126736	45118016	18·8680	
317	100489	31855013	17·8045	6·8180	357	127449	45499293	18·8944	
318	101124	32157432	17·8326	6·8260	358	128164	45882712	18·9209	
319	101761	32461759	17·8606	30	359	128881	46268279	18·9473	
320	102400	32768000	17·8885		360	129600	46656000	18·9737	

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
361	130321	47045881	19·0000	7·120	401	160801	64481201	20·0250	7·374
362	131044	47437928	19·0263	7·127	402	161604	64964808	20·0499	7·380
363	131769	47832147	19·0526	7·133	403	162409	65450827	20·0749	7·386
364	132496	48228544	19·0788	7·140	404	163216	65939264	20·0998	7·393
365	133225	48627125	19·1050	7·147	405	164025	66430125	20·1246	7·399
366	133956	49027896	19·1311	7·153	406	164836	66923416	20·1494	7·405
367	134689	49430863	19·1572	7·160	407	165649	67419143	20·1742	7·411
368	135424	49836032	19·1833	7·166	408	166464	67917312	20·1990	7·417
369	136161	50243409	19·2094	7·173	409	167281	68417929	20·2237	7·423
370	136900	50653000	19·2354	7·179	410	168100	68921000	20·2485	7·429
371	137641	51064811	19·2614	7·186	411	168921	69426531	20·2731	7·435
372	138384	51478848	19·2873	7·192	412	169744	69934528	20·2978	7·441
373	139129	51895117	19·3132	7·198	413	170569	70444997	20·3224	7·447
374	139876	52313624	19·3391	7·205	414	171396	70957944	20·3470	7·453
375	140625	52734375	19·3649	7·211	415	172225	71473375	20·3715	7·459
376	141376	53157376	19·3907	7·218	416	173056	71991296	20·3961	7·465
377	142129	53582633	19·4164	7·224	417	173889	72511713	20·4206	7·471
378	142884	54010152	19·4422	7·230	418	174724	73034632	20·4450	7·477
379	143641	54439939	19·4679	7·237	419	175561	73560059	20·4695	7·483
380	144400	54872000	19·4936	7·243	420	176400	74088000	20·4939	7·489
381	145161	55306341	19·5192	7·249	421	177241	74618461	20·5183	7·495
382	145924	55742968	19·5448	7·256	422	178084	75151448	20·5426	7·501
383	146689	56181887	19·5704	7·263	423	178929	75686967	20·5670	7·507
384	147456	56623104	19·5959	7·268	424	179776	76225024	20·5913	7·513
385	148225	57066625	19·6214	7·275	425	180625	76765625	20·6155	7·518
386	148996	57512456	19·6469	7·281	426	181476	77308776	20·6398	7·524
387	149769	57960603	19·6723	7·287	427	182329	77854483	20·6640	7·530
388	150544	58411072	19·6977	7·294	428	183184	78402752	20·6882	7·536
389	151321	58863869	19·7231	7·300	429	184041	78953589	20·7123	7·542
390	152100	59319000	19·7484	7·306	430	184900	79507000	20·7364	7·548
391	152881	59776471	19·7737	7·312	431	185761	80062991	20·7605	7·554
392	153664	60236288	19·7990	7·319	432	186624	80621568	20·7846	7·560
393	154449	60698457	19·8242	7·325	433	187489	81182737	20·8090	7·565
394	155236	61162984	19·8494	7·331	434	188356	81746504	20·8330	7·571
395	156025	61629875	19·8746	7·337	435	189225	82312875	20·8570	7·577
396	156816	62099136	19·8997	7·343	436	190096	82881856	20·8110	7·583
397	157609	62570773	19·9249	7·350	437	190969	83453453	20·9040	7·589
398	158404	63044792	19·9499	7·356	438	191844	84027672	20·9280	7·594
399	159201	63521199	19·9750	7·362	439	192721	84604519	20·9520	7·600
400	160000	64000000	20·0000	7·368	440	193600	85184000	23·9760	7·602

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
441	194481	85766121	21·000	7·612	481	231361	111284641	21·932	7·835
442	195364	86350888	21·024	7·617	482	232324	111980168	21·954	7·841
443	196249	86938307	21·048	7·623	483	233289	112678587	21·977	7·846
444	197136	87528384	21·071	7·629	484	234256	113379904	22·000	7·851
445	198025	88121125	21·095	7·635	485	235225	114084125	22·023	7·857
446	198916	88716536	21·119	7·640	486	236196	114791256	22·045	7·862
447	199809	89314623	21·142	7·646	487	237169	115501303	22·068	7·868
448	200704	89915392	21·166	7·652	488	238144	116214272	22·091	7·873
449	201601	90518849	21·190	7·657	489	239121	116930169	22·113	7·878
450	202500	91125000	21·213	7·663	490	240100	117649000	22·136	7·884
451	203401	91733851	21·237	7·669	491	241081	118370771	22·159	7·889
452	204304	92345408	21·260	7·674	492	242064	119095488	22·181	7·894
453	205209	92959677	21·284	7·680	493	243049	119823157	22·204	7·900
454	206116	93576664	21·307	7·686	494	244036	120553784	22·226	7·905
455	207025	94196375	21·331	7·691	495	245025	121287375	22·249	7·910
456	207936	94818816	21·354	7·697	496	246016	122023936	22·271	7·916
457	208849	95443993	21·378	7·703	497	247009	122763473	22·293	7·921
458	209764	96071912	21·401	7·708	498	248004	123505992	22·316	7·926
459	210681	96702579	21·424	7·714	499	249001	124251499	22·338	7·932
460	211600	97336000	21·448	7·719	500	250000	125000000	22·361	7·937
461	212521	97972181	21·471	7·725	501	251001	125751501	22·383	7·942
462	213444	98611128	21·494	7·731	502	252004	126506008	22·405	7·948
463	214369	99252847	21·517	7·736	503	253009	127263527	22·428	7·953
464	215296	99897344	21·541	7·742	504	254016	128024064	22·450	7·958
465	216225	100544625	21·564	7·747	505	255025	128787625	22·472	7·963
466	217156	101194696	21·587	7·753	506	256036	129554216	22·494	7·969
467	218089	101847563	21·610	7·758	507	257049	130323843	22·517	7·974
468	219024	102503232	21·633	7·764	508	258064	131096512	22·539	7·979
469	219961	103161709	21·656	7·769	509	259081	131872229	22·561	7·984
470	220900	103823000	21·679	7·775	510	260100	132651000	22·583	7·990
471	221841	104487111	21·703	7·780	511	261121	133432831	22·605	7·995
472	222784	105154048	21·726	7·786	512	262144	134217728	22·627	8·000
473	223729	105823817	21·749	7·791	513	263169	135005697	22·649	8·005
474	224676	106496424	21·772	7·797	514	264196	135796744	22·672	8·010
475	225625	107171875	21·794	7·802	515	265225	136590875	22·694	8·016
476	226576	107850176	21·817	7·808	516	266256	137388096	22·716	8·021
477	227529	108531333	21·840	7·813	517	267289	138188413	22·738	8·026
478	228484	109215352	21·863	7·819	518	268324	138991832	22·760	8·031
479	229441	109902239	21·886	7·824	519	269361	139798359	22·782	8·036
480	230400	110592000	21·909	7·830	520	270400	140608000	22·803	8·041

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
521	271441	141420761	22·825	8·047	561	314721	176558481	23·685	8·247
522	272484	142236648	22·847	8·052	562	315844	177504328	23·707	8·252
523	273529	143055667	22·869	8·057	563	316969	178453547	23·728	8·257
524	274576	143877824	22·891	8·062	564	318096	179406144	23·749	8·262
525	275625	144703125	22·913	8·067	565	319225	180362125	23·770	8·267
526	276676	145531576	22·935	8·072	566	320356	181321496	23·791	8·272
527	277729	146363183	22·956	8·077	567	321489	182284263	23·812	8·277
528	278784	147197952	22·978	8·082	568	322624	183250432	23·833	8·282
529	279841	148035889	23·000	8·088	569	323761	184220009	23·854	8·286
530	280900	148877000	23·022	8·093	570	324900	185193000	23·875	8·291
531	281961	149721291	23·043	8·098	571	326041	186169411	23·896	8·296
532	283024	150568768	23·065	8·103	572	327184	187149248	23·917	8·301
533	284089	151419437	23·087	8·108	573	328329	188132517	23·937	8·306
534	285156	152273304	23·108	8·113	574	329476	189119224	23·958	8·311
535	286225	153130375	23·130	8·118	575	330625	190109375	23·979	8·316
536	287296	153990656	23·152	8·123	576	331776	191102976	24·000	8·320
537	288369	154854153	23·173	8·128	577	332929	192100033	24·021	8·325
538	289444	155720872	23·195	8·133	578	334084	193100552	24·042	8·330
539	290521	156590819	23·216	8·138	579	335241	194104539	24·062	8·335
540	291600	157464000	23·238	8·143	580	336400	195112000	24·083	8·340
541	292681	158340421	23·259	8·148	581	337561	196122941	24·104	8·344
542	293764	159220088	23·281	8·153	582	338724	197137368	24·125	8·349
543	294849	160103007	23·302	8·158	583	339889	198155287	24·145	8·354
544	295936	160989184	23·324	8·163	584	341056	199176704	24·166	8·359
545	297025	161878625	23·345	8·168	585	342225	200201625	24·187	8·363
546	298116	162771336	23·367	8·173	586	343396	201230056	24·207	8·368
547	299209	163667323	23·388	8·178	587	344569	202262003	24·228	8·373
548	300304	164566592	23·409	8·183	588	345744	203297472	24·249	8·378
549	301401	165469149	23·431	8·188	589	346921	204336469	24·269	8·382
550	302500	166375000	23·452	8·193	590	348100	205379000	24·290	8·387
551	303601	167284151	23·473	8·198	591	349281	206425071	24·310	8·392
552	304704	168196608	23·495	8·203	592	350464	207474688	24·331	8·397
553	305809	169112377	23·516	8·208	593	351649	208527857	24·352	8·401
554	306916	170031464	23·537	8·213	594	352836	209584584	24·372	8·406
555	308025	170953875	23·558	8·218	595	354025	210644875	24·393	8·411
556	309136	171879616	23·580	8·223	596	355216	211708736	24·413	8·416
557	310249	172808693	23·601	8·228	597	356409	212776173	24·434	8·420
558	311364	173741112	23·622	8·233	598	357604	213847192	24·454	8·425
559	312481	174676879	23·643	8·238	599	358801	214921799	24·474	8·430
560	313600	175616000	23·664	8·243	600	360000	216000000	24·495	8·434

No.	Square.	Cube.	Square root.	Cube root	No.	Square.	Cube.	Square root.	Cube root.
601	361201	217081801	24·515	8·439	641	410881	263374721	25·318	8·622
602	362404	218167208	24·536	8·444	642	412164	264609288	25·338	8·627
603	363609	219256227	24·556	8·448	643	413449	265847707	25·35	8·631
604	364816	220348864	24·576	8·453	644	414736	267089984	25·37	8·636
605	366025	221445125	24·597	8·458	645	416025	268336125	25·397	8·640
606	367236	222545016	24·617	8·462	646	417316	269586136	25·41	8·645
607	368449	223648543	24·637	8·467	647	418609	270840023	25·436	8·649
608	369664	224755712	24 658	8·472	648	419904	272097792	25·456	8·653
609	370881	225866529	24·678	8·476	649	421201	273359449	25·475	8·658
610	372100	226981000	24·698	8·481	650	422500	274625000	25·495	8·662
611	37332	228099131	24·718	8·483	651	423801	275894451	25·515	8·667
612	374544	229220928	24·739	8·490	652	425104	277167808	25·534	8·671
613	375769	230346397	24·759	8·495	653	426409	278445077	25·554	8·676
614	376996	231475544	24·779	8·499	654	427716	279726264	25·573	8·680
615	378225	232608375	24·799	8·504	655	429025	281011375	25·593	8·685
616	379456	233744896	24·819	8·509	656	430336	282300416	25·612	8·689
617	380689	234885113	24·839	8·513	657	431649	283593393	25·632	8·693
618	381924	236029032	24·860	8·518	658	432964	284890312	25·652	8·698
619	383161	237176659	24·880	8·522	659	434281	286191179	25·671	8·702
620	384400	238328000	24·900	8·527	660	435600	287496000	25·691	8·707
621	385641	239483061	24·920	8·532	661	436921	288804781	25·710	8·711
62	386884	240641848	24·940	8·536	662	438244	290117528	25·729	8·715
623	388129	241804367	24·960	8·541	663	439569	291434247	25·749	8·720
624	389376	242970624	24·980	8·545	664	440896	292754944	25·768	8·724
625	390625	244140625	25·000	8·550	665	442225	294079625	25·788	8·729
626	391876	245314376	25·020	8·554	666	443556	295408296	25·80	8·733
627	393129	246491883	25·040	8·559	667	444889	296740963	25·826	8·737
628	394384	247673152	25·060	8·564	668	446224	29807763	25·846	8·742
629	395641	248858189	25·080	8·568	669	447561	299418309	25·865	8·746
630	396900	250047000	25·100	8·573	670	448900	300763000	25·884	3·750
631	398161	251239591	25·120	8·577	671	450241	302111711	25·904	8·755
632	399424	252435968	25·140	8·582	672	451584	303464448	25·923	8·759
633	400689	253636137	25·159	8·586	673	452929	304821217	25·942	8·763
634	401956	254840104	25·179	8·591	674	454276	306182024	25·962	8·768
635	403225	256047875	25·199	8·595	675	455625	307546875	25·981	8·772
636	404496	257259456	25·219	8·600	676	456976	308915776	26·000	8·776
637	405769	258474853	25·239	8·604	677	458329	310288733	26·019	8·781
638	407044	259694072	25·259	8·609	678	459684	311665752	26·038	8·785
639	408321	260917119	25·278	8·613	679	461041	313046839	26·058	8·789
640	409600	262144000	25·298	8·618	680	462400	314432000	26·077	8·794

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
681	463761	315821241	26·096	8·798	721	519841	374805361	26·851	8·967
682	465424	317214568	26·115	8·802	722	521284	376367048	26 870	8 971
683	466489	318611987	26·134	8 807	723	522729	377933067	26·889	8·975
684	467856	320013504	26·153	8·811	724	524176	379503424	26 907	8·979
685	469225	321419125	26·172	8·815	725	525625	381078125	26·926	8·983
686	470596	322828856	26·192	8·819	726	527076	382657176	26·944	8·988
687	471969	324242703	26·211	8·824	727	528529	384240583	26·963	8·992
688	473344	325660672	26·230	8·828	728	529984	385828352	26·981	8·996
689	474721	327082769	26·249	8·832	729	531441	387420489	27·000	9·000
690	476100	328509000	26·268	8·837	730	532900	389017000	27·019	9·004
691	477481	329939371	26·287	8·841	731	534361	390617891	27·037	9·008
692	478864	331373888	26·306	8·845	732	535824	392223168	27·055	9·012
693	480249	332812557	26·325	8·849	733	537289	393832837	27·074	9·016
694	481636	334255384	26·344	8·854	734	538756	395446904	27·092	9·021
695	483025	335702375	26·363	8·858	735	540225	397065375	27·111	9·025
696	484416	337153536	26·382	8·862	736	541696	398688256	27·129	9·029
697	485809	338608873	26·401	8·866	737	543169	400315553	27·148	9·033
698	487204	340068392	26·420	8·871	738	544644	401947272	27·166	9·037
699	488601	341532099	26·439	8·875	739	546121	403583419	27·185	9·041
700	490000	343000000	26·458	8·879	740	547600	405224000	27·203	9·045
701	491401	344472101	26·476	8·883	741	549081	406869021	27·221	9·049
702	492804	345948408	26·495	8·887	542	550564	408518488	27·240	9·043
703	494209	347428927	26·514	8·892	743	552049	410172407	27·258	9·057
704	495616	348913664	26·533	8·896	744	553536	411830784	27·276	9·061
705	497025	350402625	26·552	8·900	745	555025	413493625	27·295	9·065
706	498436	351895816	26·571	8·904	746	556516	415160936	27·313	9·069
707	499849	353393243	26·589	8·909	747	558609	416832723	27·331	9·073
708	501264	354894912	26·608	8·913	748	559504	418508992	27·350	9·078
709	502681	356400829	26·627	8·917	749	561001	420189749	27·368	9·082
710	504100	357911000	26·646	8·921	750	562500	421875000	27·386	9·086
711	505521	359425431	26·665	8·925	751	564001	423564751	27·404	9·090
712	506944	360944128	26·683	8·929	752	565504	425259008	27·423	9·094
713	508369	362477097	26·702	8·934	753	567009	426957777	27·441	9·098
714	509796	363994344	26·721	8·938	754	568516	428661064	27·459	9·102
715	511225	365525875	26·739	8·942	755	570025	430368875	27·477	9·106
716	512656	367061696	26·758	8·946	756	571536	432081216	27·495	9·110
717	514089	368601813	26·777	8·950	757	573049	433708093	27·514	9·114
718	515524	370146232	26·796	8·955	758	574564	435519512	27·532	9·118
719	516961	371694959	26·814	8·959	759	576081	437245479	27·550	9·122
720	518400	373248000	26·833	8·963	760	577600	438976000	27·568	9·126

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
761	579121	440711081	27·586	9·130	801	641601	513922401	28·302	9·287
762	580644	442450728	27·604	9·134	802	643204	515849608	28·320	9·291
763	582169	444194947	27·622	9·138	803	644809	517781627	28·337	9·295
764	583696	445943744	27·641	9·142	804	646416	519718864	28·355	9·299
765	585225	447697125	27·659	9·146	805	648025	521660125	28·373	9·302
766	586756	449455096	27·677	9·150	806	649636	523606616	28·390	9·306
767	588289	451217663	27·695	9·154	807	651249	525557943	28·408	9·310
768	589824	452984832	27·713	9·158	808	652864	527514112	28·425	9·314
769	591361	454756609	27·731	9·162	809	654481	529475129	28·443	9·318
770	592900	456533000	27·749	9·166	810	656100	531441000	28·460	9·322
771	594441	458314011	27·767	9·170	811	657721	533411731	28·478	9·326
772	595984	460099648	27·785	9·174	812	659344	535387328	28·496	9·329
773	597529	461889917	27·803	9·178	813	660969	537367797	28·513	9·333
774	599076	463684824	27·821	9·181	814	662596	539353144	28·531	9·337
775	600625	465484375	27·839	9 185	815	664225	541343375	28·548	9·341
776	602176	467288576	27·857	9·189	816	665856	543338496	28·566	9·345
777	603729	469097433	27·875	9·193	817	667489	545338513	28·583	9·348
778	605284	470910952	27·893	9·197	818	669124	547343432	28·601	9·352
779	606841	472729139	27·911	9·201	819	670761	549353259	28·618	9·356
780	608400	474552000	27·928	9·205	820	672400	551368000	28·636	9·360
781	609961	476379541	27·946	9·209	821	674041	553387661	28·653	9·364
782	611524	478211768	27·964	9·213	822	675684	555412248	28·671	9·367
783	613089	480048687	27·982	9·217	823	677329	557441767	28·688	9·371
784	614656	481890304	28·000	9·221	924	678976	559476224	28·705	9·375
785	616225	483736625	28·018	9·225	825	680625	561515625	28·723	9·379
786	617796	485587656	28·036	9·229	826	682276	563559976	28·740	9·383
787	619369	487443403	28·054	9·233	827	683929	565609283	28·758	9·386
788	620944	489303872	28·071	9·237	828	685584	567663552	28·775	9 390
789	622521	491169069	28·089	9·240	829	687241	569722789	28·792	9·394
790	624100	493039000	28·107	9·244	830	688900	571787000	28·810	9·398
791	625681	494913671	28·125	9·248	831	690561	573856191	28·827	9·402
792	627264	496793088	28·142	9·252	832	692224	575930368	28·844	9·405
793	628849	498677257	28·160	9·256	833	693889	578009537	28·862	9·409
794	630436	500566184	28·178	9·260	834	695556	580093704	28·879	9·413
795	632025	502459875	28·196	9·264	835	697225	582182875	28·896	9·417
796	633616	504358336	28·213	9·268	836	698896	584277056	28·914	9·420
797	635209	506261573	28·231	9·272	837	700569	586376253	28·931	9·424
798	636804	508169592	28·249	9·275	838	702244	588480472	28·948	9·428
799	638401	510082399	28·267	9·279	839	703921	590589719	28·965	9·432
800	640000	512000000	28·284	9·283	840	705600	592704000	28·983	9·435

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
841	707281	594823321	29·000	9·439	881	776161	683797841	29·682	9·586
842	708964	596947688	29·017	9·443	882	777924	686128968	29·698	9·590
843	710649	599077107	29·034	9·447	883	779689	688465387	29·715	9·594
844	712336	601211584	29·052	9·450	884	781456	690807104	29·732	9·597
845	714025	603351125	29·069	9·454	885	783225	693154125	29·749	9·601
846	715716	605495736	29·086	9·458	886	784996	695506456	29·766	9·605
847	717409	607645423	29·103	9·462	887	786769	697864103	29·783	9·608
848	719104	609800192	29·120	9·465	888	788544	700227072	29·799	9·612
849	720801	611960049	29·138	9·469	889	790321	702595369	29·816	9·615
850	722500	614125000	29·155	9·473	890	792100	704969000	29·833	9·619
851	724201	616295051	29·172	9·476	891	793881	707347971	29·850	9·623
852	725904	618470208	29·189	9·480	892	795664	709732288	29·866	9·626
853	727609	620650477	29·206	9·484	893	797449	712121957	29·883	9·630
854	729316	622835864	29·223	9·488	894	799236	714516984	29·900	9·633
855	731025	625026275	29·240	9·491	895	801025	716917375	29·917	9·637
856	732736	627222016	29·257	9·495	896	802816	719323136	29·933	9·641
857	734449	629422793	29·275	9·499	897	804609	721734273	29·950	9·644
858	736164	631628712	29·292	9·502	898	806404	724150792	29·967	9·648
859	737881	633839779	29·309	9·506	899	808201	726572699	29·983	9·651
860	739600	636056000	29·326	9·510	900	810000	729000000	30·000	9·655
861	741321	638277381	29·343	9·513	901	811801	731432701	30·017	9·658
862	743044	640503928	29·360	9·517	902	813604	733870808	30·033	9·662
863	744769	642735647	29·377	9·521	903	815409	736314327	30·050	9·666
864	746496	644972544	29·394	9·524	904	817216	738763264	30·067	9·669
865	748225	647214625	29·411	9·528	905	819025	741217625	30·083	9·673
866	749956	649461896	29·428	9·532	906	820836	743677416	30·100	9·676
867	751689	651714363	29·445	9·535	907	822649	746142643	30·116	9·680
868	753424	653972032	29·462	9·539	908	824464	748613312	30·133	9·683
869	755161	656234909	29·479	9·543	909	826281	751089429	30·150	9·687
870	756900	658503000	29·496	9·546	910	828100	753571000	30·166	9·691
871	758641	660776311	29·513	9·550	911	829921	756058031	30·183	9·694
872	760384	663054848	29·530	9·554	912	831744	758550528	30·199	9·698
873	762129	665338617	29·547	9·557	913	833569	761048497	30·216	9·701
874	763876	667627624	29·563	9·561	914	835396	763551944	30·232	9·705
875	765625	669921875	29·580	9·565	915	837225	766060875	30·249	9·708
876	767376	672221376	29·597	9·568	916	839056	768575296	30·265	9·712
877	769129	674526133	29·614	9·572	917	840889	771095213	30·282	9·715
878	770884	676836152	29·631	9·576	918	842724	773620632	32·299	9·719
879	772641	679151439	29·648	9·579	919	844561	776151559	30·315	9·722
880	774400	681472000	29·665	9·583	920	846400	778688000	30·331	9·726

No.	Square.	Cube.	Square root.	Cube root.	No.	Square.	Cube.	Square root.	Cube root.
921	848241	781229961	30·34	9·72	96	92352	8875036	31·00	
922	85008	78377744	30·36	9·73	96	925444	89027712	31·01	
923	8519	78633046	30·38	9·73	96	92736	89305634	31·03	
924	85377	78888902	30·39	9·74	96	92929	89584134	31·04	
925	8556	79145312	30·41	9·74	96	93122	8986321	31·064	
926	85747	79402277	30·43	9·74	96	93315	90142869	31·08	
927	85932	79659798	30·44	9·7	96	93508	0423106	31·09	
928	86118	79917875	30·46	9·75	96	9370	90703923	31·11	
929	86304	80176508	30·4	9·7	96	93896	90985320	31·12	
930	86490	80435700	30·49	9·76	97	94090	9126730	31·14	
931	86676	80695449	30·51	9·76	97	94284	1549861	31·16	
932	86862	80955756	30·52	9·76	97	94478	1833004	31·177	
933	87048	31216623	30·54	9·77	97	94672	2116731	31·193	
934	87235	31478050	30·56	9·77	97	94867	2401042	31·209	
935	87422	1740037	30·57	9·77	97	95062	2685937	31·225	
936	87609	20025856	30·594	9·78	97	95257	29714176	31·241	
937	87796	2265695	30·61	9·78	97	95452	32574833	31·257	
938	879844	25293672	30·62	9·78	97	956484	35441352	31·273	
939	88172	2793601	30·64	9·79	97	95844	38313739	31·28	
940	88360	30584000	30·65	9·796	98	96040	41192000	31·305	
941	885481	333237621	30·676	9·79	981	962361	944076141	31·321	
942	887364	335896888	30·692	9·803	982	964324	46966168	31·337	
943	889249	38561807	30·708	9·806	983	966289	49862087	31·353	
944	891136	41232384	30·725	9·81	984	968256	52763904	31·369	
945	893025	343908625	30·741	9·813	985	970225	5567162	31·385	
946	894916	46590536	30·757	9·817	986	972196	58585256	31·401	
	896909	349278123	30·773	9·82	98	974169	61504803	31·417	
	898704	1971392	30·79	9·824	988	976144	64430272	31·432	
949	900601	54670349	30·806	9·827	98	978121	67361669	31·448	
950	902500	57375000	30·822	9·830	990	980100	70299000	31·464	
951	904401	60085351	30·83	9·834	991	82081	3242271	31·480	
952	906304	2801408	30·854	837	99	984064	6191488	31·496	
953	908209	35523177	30·871	9·841	993	986049	9146657	31·512	
954	910116	8250664	30·887	9·844	994	88036	2107784	31·528	
955	912025	0983875	30·903	9·848	995	990025	85074875	31·544	
956	913936	3722816	30·919	9·851	96	992016	8047936	31·559	9·987
957	915849	6467493	30·935	9·855	997	994009	1026973	31·575	9·990
958	917764	9217912	30·952	9·858	98	96004	94011992	31·591	9·993
959	919681	1974079	30·968	861	99	98001	7002999	31·607	9·997
960	921600	84736000	30·983	9·865	000	00001	000000000	31·623	10·000

Squares, Cubes, etc. of fractions.

Number. N	N^2	N^3	N^4	N^5	$\sqrt[2]{N}$	$\sqrt[3]{N}$	$\sqrt[4]{N}$	Reciprocals
$\frac{1}{16}$	·0039	·00024	·000015	·000001	·25	·3969	·5	16
$\frac{1}{8}$	·0156	.0020	·00024	·000031	·3536	·5	·595	8
$\frac{3}{16}$	·0352	·0066	·00124	·000232	·4330	·5724	·658	5·333
$\frac{1}{4}$	·0625	·0156	·00391	·000977	·5	·6300	·707	4
$\frac{5}{16}$	·0977	·0305	·00953	·00298	·5590	·6786	·748	3·2
$\frac{3}{8}$	·1406	·0527	·0198	·00742	·6124	·7212	·783	2·657
$\frac{7}{16}$	·1914	·0837	·0366	·01601	·6614	·7591	·813	2·286
$\frac{1}{2}$	·25	·125	·0625	·03125	·7071	·7937	·849	2·
$\frac{9}{16}$	·3164	·1780	·1001	·0563	·7500	·8255	·866	1·778
$\frac{5}{8}$	·3906	·2441	·1526	·0954	·7906	·8550	·889	1·6
$\frac{11}{16}$	·4727	·3250	·2234	·1536	·8292	·8826	·911	1·455
$\frac{3}{4}$	·5625	·4219	·3164	·2373	·8660	·9086	·930	1·333
$\frac{13}{16}$	·6602	·5364	·4359	·3363	·9014	·9331	·950	1·231
$\frac{7}{8}$	·7656	·6699	·5862	·5129	·9354	·9565	·967	1·143
$\frac{15}{16}$	·8789	·8240	·7725	·7242	·9682	·9787	·989	1·067
1	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0

Table of Circumferences of Circles.

Diam.	Circumferences.							
	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
0	·0	·3927	·7854	1·178	1·570	1·963	2·356	2·748
1	3·141	3·534	3·927	4·319	4·712	5·105	5·497	5·890
2	6·283	6·675	7·068	7·46	7·854	8·246	8·639	9·[illegible]32
3	9·424	9·817	10·21	10·60	10·99	11·38	11·78	12·17
4	12·56	12·95	13·35	13·74	14·13	14·52	14·92	15·31
5	15·70	16·10	16·49	16·88	17·27	17·67	18·06	18·45
6	18·84	19·24	19·63	20·02	20·42	20·81	21·20	21·59
7	21·99	22·38	22·77	23·16	23·56	23·95	24·34	24·74
8	25·13	25·52	25·91	26·31	26·70	27·09	27·48	27·88
9	28·27	28·66	29·05	29·45	29·84	30·23	30·63	31·02
10	31·41	31·80	32·20	32·59	32·98	33·37	33·77	34·16

Table of Circumferences of Circles.

Diam.	Circumferences.							
	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
11	34·55	34·95	35·34	35·73	36·12	36·52	36·91	37·30
12	37·69	38·09	38·48	38·87	39·27	39·66	40·05	40·43
13	40·84	41·23	41·62	42·01	42·41	42·80	43·19	43·58
14	43·98	44·37	44·76	45·16	45·55	45·94	46·33	46·73
15	47·12	47 51	47·90	48 30	48·69	49·08	49·48	49·87
16	50·26	50·05	51·05	51·44	51·83	52·22	52·62	53·01
17	53·40	53·79	54·19	54·58	54·97	55·37	55·76	56·19
18	56·54	56·94	57·33	57·72	58·11	58·51	58·90	59·29
19	59·69	60·08	60·47	60·86	61 26	61·65	62·04	62·43
20	62·83	63·22	63·61	64·01	64·40	64·79	65·18	65·58
21	65·97	66·36	66·75	67·15	67·54	67·93	68·32	68·72
22	69·11	69·50	69·90	70·29	70·60	71·07	71·47	71·86
23	72·25	72·64	73·04	73·43	73·82	74·22	74·61	75·00
24	75·39	75·79	76·18	76·57	76·96	77·36	77·75	78·14
25	78·54	78·93	79·32	79·71	80·10	80·50	80·89	81·23
26	81·68	82·07	82·46	82·85	83·25	83·64	84·03	84·43
27	84·82	85·21	85·60	86·00	86·39	86·78	87·17	87·57
28	87·96	88·35	88·75	89·14	89·53	89·92	90·32	90·71
29	91·10	91·49	91·89	92·28	92·67	93·06	93·46	93·85
30	94·24	94·64	95·03	95·42	95·81	96·21	96·60	96·99
31	97·4	97·8	98·2	98·6	99·0	99·4	99·7	100·1
32	100·5	100·9	101·3	101·7	102·1	102·5	102·9	103·3
33	103·7	104·1	104·5	104·9	105·2	105·6	106·0	106·4
34	106·8	107·2	107·6	108·0	108·4	108·8	109·2	109·6
35	110·0	110·3	110·7	111·1	111·5	111·9	112·3	112·7
36	113·1	113·5	113·9	114·3	114·7	115·1	115·5	115·8
37	116·2	116·6	117·0	117·4	117·8	118·2	118·6	119·0
38	119·4	119·8	120·2	120·6	121·0	121·7	121·7	122·1
39	122·5	122·9	123·3	123·7	124·1	124·5	124·9	125·3
40	125·7	126·1	126·4	126·8	127·2	127·6	128·0	128·4
41	128·8	129·2	129·6	130·0	130·4	130·8	131·2	131·6
42	131·9	132·3	132·7	133·1	133·5	133·9	134·3	134·7
43	135·1	135·5	135·9	136·3	136·7	137·1	137·4	137·8
44	138·2	138·6	139·0	139·4	139·8	140·2	140·6	141·0
45	141·1	141·8	142·2	142·9	142·9	143·3	143·7	144·1
46	144·5	144·9	145·3	145·7	146·1	146·5	146·9	147·3
47	147·7	148·0	148·4	148·8	149·2	149·6	150·0	150·4
48	150·8	151·2	151·6	152·0	152·4	152·8	153·2	153·5

49	153·9	154·3	154·7	155·1	155·5	155·9	156·3	156·7
50	157·1	157·5	157·9	158·3	158·7	159·0	159·4	159·8
51	160·2	160·6	161·0	161·4	161·8	162·2	162·6	163·0
52	163·4	163·8	164·1	164·5	164·9	165·3	165·7	166·1
53	166·5	166·9	167·3	167·7	168·1	168·5	168·9	169·3
54	169·6	170·0	170·4	170·8	171·2	171·6	172·0	172·5
55	172·8	173·2	173·6	174·0	174·4	174·8	175·1	175·5

Table of Areas of Circles.

Diam.	Areas.							
	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
0	·00	0·122	·0490	·1104	·1963	·3068	·4417	·6013
1	·7854	·9940	1·227	1·484	1·767	2·073	2·505	2·761
2	3·141	3·546	3·976	4·430	4·908	5·411	5·939	6·491
3	7·068	7·669	8·295	8·946	9·621	10·32	11·04	11·79
4	12·56	13·36	14·18	15·03	15·90	16·80	17·72	18·66
5	19·63	20·62	21·64	22·69	23·75	24·85	25·96	27·10
6	28·27	29·46	30·68	31·91	33·18	34·47	35·78	37·12
7	38·48	39·87	41·28	42·71	44·17	45·66	47·17	48·70
8	50·26	51·84	53·45	55·08	56·74	55·42	60·13	61·86
9	63·61	65·39	67·20	69·02	70·89	72·76	74·66	76·58
10	78·54	80·51	82·51	84·54	86·59	88·66	90·76	92·88
11	95·03	97·20	99·40	101·6	103·8	106·1	108·4	110·7
12	113·1	115·4	117·9	120·2	122·7	125·1	127·6	130·1
13	132·7	135·3	137·8	140·5	143·1	145·8	148·4	151·3
14	153·9	156·6	159·4	162·2	165·1	167·0	170·8	173·7
15	176·7	179·6	182·6	185·6	188·6	191·7	194·8	197·9
16	201·1	204·2	207·3	210·5	213·8	217·0	220·3	223·6
17	226·9	230·3	233·7	237·1	240·5	243·9	247·4	250·9
18	254·4	258·0	261·5	265·1	268·8	272·4	276·1	279·8
19	283·5	287·2	291·0	294·8	298·6	302·4	306·3	310·2
20	314·1	318·1	322·0	326·0	330·0	334·1	338·1	342·2
21	346·3	350·4	354·6	358·8	363·0	367·2	371·5	375·8
22	380·1	384·4	388·8	393·2	397·6	402·0	406·4	410·9
23	415·4	420·0	424·5	429·1	433·7	438·3	443·0	447·6
24	452·3	457·1	461·8	466·6	471·4	476·2	481·1	485·9
25	490·9	495·7	500·7	505·7	510·7	515·7	520·7	525·8
26	530·9	536·0	541·1	546·3	551·5	556·7	562·0	567·2
27	572·5	577·8	583·2	588·5	593·9	599·3	604·8	610·2
28	615·7	621·2	626·7	632·3	637·1	543·5	649·1	654·8
29	660·5	666·2	671·9	677·7	683·4	689·2	696·1	700·9
30	706·8	712·7	718·6	724·6	730·6	736·6	742·6	748·6

Table of Areas of Circles—concluded.

Diam.	Areas.							
	0	⅛	¼	⅜	½	⅝	¾	⅞
31	754·8	760·9	767·0	773·1	779·3	785·5	791·7	798·0
32	804·2	810·5	816·9	823·2	829·6	836·0	842·4	848·8
33	855·3	861·8	868·3	874·8	881·4	888·6	894·6	901·3
34	907·9	914·6	921·3	928·1	934·8	941·6	948·4	955·3
35	962·1	969·0	975·9	982·8	989·8	996·8	1003·8	1010·8
36	1017·9	1025·0	1032·1	1039·2	1046·4	1053·5	1060·7	1068·0
37	1075·2	1082·5	1089·8	1097·1	1104·5	1111·7	1119·2	1126·7
38	1134·1	1141·6	1149·1	1156·6	1164·2	1171·7	1179·3	1186·9
39	1194·6	1202·3	1210·0	1217·7	1225·4	1233·2	1241·0	1248·8
40	1256·6	1264·5	1272·4	1280·3	1288·3	1296·2	1304·2	1312·2
41	1320·3	1328·3	1336·4	1344·5	1352·7	1360·8	1369·0	1377·2
42	1385·4	1393·7	1402·0	1410·3	1418·6	1427·0	1435·4	1443·8
43	1452·2	1460·7	1469·1	1477·6	1486·2	1494·7	1503·3	1511·9
44	1520·5	1529·2	1537·9	1546·6	1555·3	1564·6	1572·8	1581·6
45	1590·4	1599·3	1608·2	1617·0	1626·0	1634·9	1643·9	1652·9
46	1661·9	1671·0	1680·0	1689·1	1699·2	1707·4	1716·5	1725·7
47	1734·9	1744·2	1753·5	1762·7	1772·1	1781·4	1790·8	1800·1
48	1809·6	1819·0	1828·5	1837·9	1847·5	1857·0	1866·6	1876·1
49	1885·7	1895·4	1905·0	1914·7	1924·4	1934·2	1943·9	1953·7
50	1963·5	1973·3	1983·2	1993·1	2003·0	2012·9	2022·8	2032·8
51	2042·8	2052·9	2062·9	2073·0	2083·1	2093·2	2103·4	2113·5
52	2123·7	2133·9	2144·2	2154·5	2164·8	2175·1	2185·4	2195·8
53	2206·2	2216·6	2227·1	2237·5	2248·0	2258·5	2269·1	2279·6
54	2290·2	2300·8	2311·5	2322·1	2332·8	2343·5	2354·3	2365·0
55	2375·8	2386·6	2397·5	2408·3	2419·2	2430·2	2441·1	2452·0
56	2463·0	2474·0	2485·1	2496·1	2507·2	2518·3	2529·4	2540·6
57	2551·8	2563·0	2574·2	2585·4	2596·7	2608·3	2619·4	2630·7
58	2642·1	2653·5	2664·2	2676·4	2687·8	2699·3	2710·9	2722·4
59	2734·0	2745·6	2757·2	2768·8	2780·5	2792·2	2803·9	2815·7
60	2827·4	2839·2	2851·1	2862·9	2874·8	2886·7	2898·6	2910·5

Circumference of Circles advancing by 10ths.

Diam.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	·0000	·3142	·6823	·9425	1·2566	1·5708	1·8850	2·1991	2·5133	2·8274
1	3·1416	3·4557	3·7699	4·0840	4·3982	4·7124	5·0265	5·3407	5·6558	5·9690
2	6·2832	6·5973	6·9115	7·2256	7·5398	7·8540	8·1681	8·4823	8·7964	9·1106
3	9·4248	9·7389	10·0531	10·3672	10·6814	10·9956	11·3097	11·6239	11·9380	12·2522
4	12·5664	12·8805	13·1947	13·5088	13·8230	14·1372	14·4513	14·7655	15·0796	15·3938
5	15·7080	16·0221	16·3363	16·6504	16·9646	17·2788	17·5929	17·9071	18·2212	18·5354
6	18·8496	19·1637	19·4779	19·7920	20·1062	20·4204	20·7345	21·0487	21·3628	21·6770
7	21·9912	22·3053	22·6195	22·9336	23·2478	23·5620	23·8761	24·1903	24·5044	24·8186
8	25·1328	25·4469	25·7611	26·0752	26·3894	26·7036	27·0177	27·3319	27·6460	27·9602
9	28·2744	28·5885	28·9027	29·2168	29·5310	29·8452	30·1593	30·4735	30·7876	31·1018
10	31·4160	31·7301	32·0443	32·3580	32·6726	32·9868	33·3009	33·6150	33·9292	34·2434
11	34·5576	34·8717	35·1859	35·5010	35·8142	36·1284	36·4425	36·7567	37·0708	37·3840
12	37·6992	38·0133	38·3275	38·6416	38·9558	39·2700	39·5841	39·8983	40·2124	40·5266
13	40·8408	41·1549	41·4691	41·7832	42·0974	42·4116	42·7257	43·0399	43·3540	43·6682
14	43·9824	44·2965	44·6107	44·9248	45·2390	45·5532	45·8673	46·1815	46·4956	46·8098
15	47·1240	47·4381	47·7523	48·0664	48·3806	48·6948	49·0080	49·3321	49·6372	49·9514
16	50·2656	50·5797	50·8939	51·2080	51·5224	51·8364	52·1505	52·4647	52·7788	53·0930
17	53·4072	53·7213	54·0355	54·3496	54·6038	54·9780	55·2921	55·6063	55·9204	56·2346
18	56·5488	56·8629	57·1771	57·4912	57·8054	58·1196	58·4337	59·7479	59·0620	59·3762
19	59·6904	60·0045	60·3187	60·6328	60·9170	61·2612	61·5753	61·8895	62·2036	62·5178
20	62·8320	63·1461	63·4603	63·7744	64·0886	64·4028	64·7161	65·0311	65·3452	65·6594
21	65·9736	66·2870	66·6012	66·7916	67·2930	67·5444	67·8585	68·1727	68·4868	68·8010
22	69·1152	69·4293	69·7435	70·0576	70·3718	70·6860	71·0001	71·3143	71·6284	71·9426
23	72·2568	72·5709	72·8851	73·1992	73·5134	73·8276	74·1417	74·4559	74·7680	75·0882
24	75·3984	75·7125	76·0267	76·3408	76·6523	76 9692	77·2833	77·5975	77·9116	78·2258
25	78·5400	78·8541	79·1683	79·4824	79·7966	80·8108	80·4249	80·7391	81·0532	81·3674

Circumference of Circles advancing by 10ths (concld.).

Diam.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
26	81·6815	81·9955	82·3097	82·6240	82·9382	83·2524	83·5665	83·8807	84·1948	84·5090
27	84·8232	85·1373	85·4515	85·7656	86·0798	86·3940	86·7081	87·0223	87·3364	87·6506
28	87·9648	88·2789	88·5931	88·9072	89·2214	89·5315	89·8497	90·1639	90·4780	90·7922
29	91·1064	91·4205	91·7347	92·0488	92·3630	92·6772	92·9913	93·3055	93·6196	93·9338
30	94·2480	94·5621	94·8763	95·1904	95·5046	95·8188	96·1329	96·4471	96·7612	97·0754
31	97·3896	97·7037	98·0179	98·3320	98·6452	98·9604	99·2745	99·5887	99·9028	100·217
32	100·531	100·845	101·160	101·474	101·748	102·102	102·416	102·730	103·044	103·359
33	103·673	103·987	104·301	104·615	104·929	105·244	105·558	105·872	106·186	106·500
34	106·814	107·129	107·427	107·757	108·071	108·385	108·699	109·035	109·308	109·642
35	109·956	110·270	110·584	110·898	111·213	111·527	111·841	112·155	112·469	112·783
36	113·098	113·412	113·726	114·040	114·354	114·668	114·983	115·297	115·611	115·925
37	116·239	116·553	116·868	117·182	117·496	117·810	118·124	118·438	118·752	119·067
38	119·381	119·695	120·009	120·323	120·637	120·952	121·266	121·580	121·894	122·208
39	122·522	122·837	123·151	123·465	123·779	124·093	124·407	124·722	125·036	125·350
40	125·664	125·978	126·292	126·606	126·921	127·235	127·549	127·863	128·177	128·491
41	128·806	129·120	129·432	129·748	130·062	130·376	130·691	131·005	131·319	131·632
42	131·947	132·261	132·576	132·800	133·204	133·518	133·832	134·146	134·460	134·775
43	135·089	135·403	135·717	136·033	136·345	136·660	136·974	137·288	137·602	137·916
44	138·230	138·545	138·859	139·173	139·487	139·801	140·115	140·430	140·744	141·058
45	141·372	141·686	142·000	142·314	142·629	142·943	143·257	143·571	143·885	144·199
46	144·514	144·828	145·142	145·456	145·770	146·084	146·399	146·713	147·027	147·341
47	147·655	147·969	148·284	148·598	148·912	149·226	149·536	149·854	150·168	150·483
48	150·797	151·111	151·425	151·739	152·053	152·368	152·682	152·996	153·310	153·624
49	153·938	154·253	154·567	154·881	155·195	155·509	155·823	156·138	156·452	156·756
50	157·080	157·394	157·708	158·022	158·337	158·651	158·965	159·279	159·593	159·907

Areas of Circles advancing by 10ths.

Diam.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	·0000	·0078	·0314	·0706	·1256	·1963	·2827	·3848	·5026	·6361
1	·7854	·9503	1·1309	1·3273	1·5393	1·7671	2·0106	2·2698	2·5446	2·8352
2	3·1416	3·4636	3·8013	4·1547	4·5239	4·9087	5·3093	5·7255	6·1575	6·6052
3	7·0686	7·5476	8·0424	8·5530	9·0792	9·6211	10·1787	10·7521	11·3411	11·9459
4	12·5664	13·2025	13·8544	14·5220	15·2053	15·9043	16·6190	17·3494	18·0956	18·8574
5	19·6350	20·4282	21·2372	22·0618	22·9022	23·7583	24·6301	25·5176	26·4208	27·3397
6	28·2744	29·2247	30·1907	31·1725	32·1699	33·1831	34·2120	35·2566	36·3168	37·3928
7	38·4846	39·5920	40·7151	41·8539	43·0085	44·1787	45·3647	46·6663	47·7837	49·0168
8	50·2656	51 5300	52·8102	54·1062	55·4178	56·7451	58·0881	59·4469	60·8213	62·2415
9	63·6174	65·0389	66·4762	67·9292	69·3979	70·8823	72·3824	73·8982	75·4298	76·9770
10	78·5400	80·1186	81·7130	83·2329	84·9488	86·5903	88·2475	89·9204	91·6090	93·3133
11	95·0334	96·7691	98·5205	100·2877	102·0705	103·8691	105·6834	107·5134	109·3590	111·2204
12	113·0976	114·9904	116·8989	118·8231	120·7631	122·7187	124·6901	126·6771	128·6799	130·6984
13	132·7326	134·7824	136·8480	138·9294	141·0264	143·1391	145·2675	147·4117	149·5715	151·7471
14	153·9384	156·1453	158·3680	160·6064	162·8605	165·1303	167·4158	169·7170	172·0340	174·3666
15	176·7150	179·0790	181·4588	183·8542	186·2654	188·6923	191·1349	193·5932	196·0672	198·5560
16	201·0624	203·5835	206·1209	208·6723	211·1411	213·8251	216·4248	219·0402	221·6712	224·3189
17	226·9086	229·6588	232·3527	235·0623	237·7877	240·5287	243·2855	246·0579	248·8461	251·6500
18	254·4696	257·3046	260·1558	263·0226	265·9050	268·8031	271·7169	274·6465	277·5917	280·5527
19	283·5294	286·5217	289·5298	292·5536	295·5931	298·6483	301·7192	304·8060	307·3082	311·0252
20	314·1600	317·3094	320·4746	323·6554	326·8520	330·0643	333·2923	336·3360	339·6954	343·0705
21	346·3614	349·6679	352·9901	356·3281	359·6817	363·0511	366·4362	369·8373	373·2534	376·6856
22	380·1336	383·5972	387·0765	390·5751	394·0823	397·6087	401·1509	404·7087	408·2823	411·8716
23	415·7766	419·0972	422·7336	426·3858	430·0536	433·7371	437·4363	441·1511	344·8819	448·6283
24	452·3904	456·1681	459·9616	463·7708	467·5957	471·4363	475·2926	479·1646	483·0524	486·9550
25	490·8750	494·8098	498·7604	502·7266	506·7086	510·7063	514·7196	518·7488	522·7936	526·8541

Areas of Circles advancing by 10ths—(concluded).

Diam.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
26	530·9304	535·0223	539·1299	543·2533	547·3923	551·5471	555·7176	559·9038	564·1056	568·3232
27	572·5566	576·8056	581·0703	585·3507	589·6469	593·9587	598·2863	602·6295	606·9885	611·3622
28	615·7536	620·1596	624·5814	629·0190	633·4722	637·6411	642·4257	646·9261	651·4421	655·9739
29	660·5214	665·0845	669·6634	674·2580	678·8683	683·4943	688·1360	692·7934	697·4666	702·1554
30	706·8600	711·5802	716·3162	721·0678	725·8352	730·6183	735·4171	740·2316	745·0618	749·9077
31	754·7694	759·6467	764·5397	769·4485	774·3729	779·3131	784·2689	789·2406	794·2278	799·2308
32	804·2496	809·2840	814·3341	819·3999	824·4815	829·5787	834·6917	839·8203	844·9647	850·1248
33	855·3006	860·4920	865·6992	870·9222	876·1608	981·4151	886·6851	891·9709	897·2723	902·5895
34	907·9224	913·2709	918·6352	924·0115	929·4109	934·8223	940·2494	945·6922	951·1508	956·6250
35	962·1150	967·6206	973·1420	978·6790	984·2318	989·8003	995·3845	1000·984	1006·600	1012·231
36	1017·878	1023·541	1029·220	1034·913	1040·624	1046·349	1052·090	1057·8474	1063·620	1069·408
37	1075·213	1081·032	1086·868	1092·719	1098·586	1104·769	1110·367	1116·281	1122·211	1128·156
38	1134·118	1140·095	1146·087	1152·095	1158·119	1164·159	1170·215	1176·286	1182·373	1188·465
39	1194·539	1200·727	1206·877	1213·042	1219·224	1225·420	1231·633	1237·961	1244·121	1250·365
40	1256·640	1262·931	1269·239	1275·560	1281·898	1288·252	1294·622	1301·007	1307·408	1313·825
41	1320·257	1326·706	1333·169	1339·649	1346·144	1352·655	1359·182	1365·724	1372·282	1378·856
42	1385·446	1392·051	1398·672	1405·308	1411·961	1418·629	1425·313	1432·012	1438·727	1445·458
43	1452·205	1458·967	1465·745	1472·539	1479·348	1486·173	1493·014	1499·871	1506·743	1513·629
44	1520·534	1527·454	1534·389	1541·340	1548·306	1555·288	1562·286	1569·300	1576·329	1583·374
45	1590·435	1597·511	1604·604	1611·711	1618·835	1625·974	1633·129	1640·302	1647·486	1654·689
46	1661·906	1669·140	1676·389	1683·654	1690·935	1698·231	1705·543	1712·871	1720·214	1727·574
47	1734·949	1742·339	1749·746	1757·168	1764·605	1772·059	1779·528	1787·013	1794·513	1802·030
48	1809·562	1817·109	1824·673	1832·252	1839·847	1847·457	1855·083	1862·725	1870·383	1878·056
49	1885·745	1893·450	1901·171	1908·907	1916·659	1924·426	1932·210	1940·009	1947·263	1955·654
50	1963·500	1971·362	1979·239	1987·133	1995·042	2002·966	2010·907	2018·663	2026·835	2034·877

Circumference of Circles advancing by 12ths.

Diam.	0	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	9/12	10/12	11/12
0	·00000	·26180	·52360	·78540	1·0472	1·3090	1·5708	1·8326	2·0944	2·3562	2·6180	2·8798
1	3·1416	3·4034	3·6652	3·9270	4·1888	4·4506	4·7124	4·9742	5·2360	5·4978	5·7596	6·0214
2	6·2832	6·5450	6·8068	7·0686	7·3304	7·5922	7·8540	8·1158	8·3776	8·6394	8·9012	9·1630
3	9·4248	9·6866	9·9484	10·2102	10·4720	10·7338	10·9956	11·2574	11·5192	11·7810	12·0428	12·3046
4	12·5664	12·8282	13·0900	13·3518	13·6136	13·8754	14·1372	14·3990	14·6608	14·9226	15·1844	15·4462
5	15·7080	15·9698	16·2316	16·4934	16·7552	17·0170	17·2788	17·5406	17·8024	18·0642	18·3260	18·5872
6	18·8496	19·1114	19·3732	19·6350	19·8968	20·1586	20·4204	20·6822	20·9440	21·2058	21·4676	21·7294
7	21·9912	22·2530	22·5148	22·7766	23·0384	30·3002	23·5620	23·8238	24·0856	24·3474	24·6092	24·8710
8	25·1328	25·3946	25·6564	25·9182	26·1800	26·4418	26·7036	26·9654	27·2272	27·4890	27·7508	28·0126
9	28·2744	28·5362	28·7980	29·0598	29·3216	29·5834	29·8452	30·1070	30·3688	30·6306	30·8924	31·1542
10	31·4160	31·6778	31·9396	32·2014	32·4632	32·7250	32·9868	33·2486	33·5104	33·7722	34·0340	34·2958
11	34·5576	34·8194	35·0812	35·3430	35·6048	35·8666	36·1284	36·3902	36·6520	36·9138	37·1756	34·4374
12	37·6992	37·9610	38·2228	38·4846	38·7464	39·0082	39·2700	39·5318	39·7936	40·0554	40·3172	40·5790
13	40·8408	41·1026	41·3644	41·6262	41·8880	42·1498	42·4116	42·6734	42·9352	43·1970	43·4588	43·7206
14	43·9824	44·2442	44·5060	44·7678	45·0296	45·2914	45·5532	45·8150	46·0678	46·3386	46·6004	46·8622
15	47·1240	47·3858	47·6476	47·9094	48·1712	48·4330	48·6948	48·9566	49·2184	49·4802	49·7420	50·0038
16	50·2656	50·5274	50·7892	51·0510	51·3128	51·5746	51·8364	52·0982	52·3600	52·6218	52·8836	53·1454
17	53·4072	53·6690	53·9308	54·1926	54·4544	54·7162	54·9780	55·2398	55·5516	55·7634	56·0252	56·2870
18	56·5488	56·8106	57·0724	57·3342	57·5960	57·8578	58·1196	58·3814	58·6432	58·9050	59·1668	59·4280
19	59·6904	59·9522	60·2140	60·4758	60·7376	60·9994	61·2612	61·5230	61·7848	62·0466	62·3084	62·5702
20	62·8320	63·0938	63·3556	63·6174	63·8792	64·1410	64·4028	64·6646	64·9264	65·1882	65·4500	65·7118
21	65·9736	66·2354	66·4972	66·7590	67·0208	67·2826	67·5444	67·8062	68·0680	68·3298	68·5916	68·8534
22	69·1152	69·3770	69·6388	69·9006	70·1624	70·4242	70·6860	70·9478	71·2096	71·4714	71·7332	71·9950
23	72·2588	72·5186	72·7804	73·0422	73·3040	73·5658	73·8276	74·0894	74·3512	74·6130	74·8748	75·1366
24	75·3984	75·6602	75·9220	76·1838	76·4456	76·7074	76·9692	77·2310	77·4928	77·7546	78·0164	78·2882
25	78·5400	78·8018	79·0636	79·3254	79·5872	79·8490	80·1108	80·3726	80·6344	80·8962	81·1580	81·4198
26	81·6816	81·9434	82·2052	82·4670	82·7288	82·9906	83·2525	83·5142	83·7760	84·0378	84·2996	84·5614

Circumference of Circles advancing by 12ths—(conclud).

Diam.	0	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	9/12	10/12	11/12
27	84·8332	85·0850	85·3468	85·6086	85·8704	86·1322	86·3949	86·6558	86·9176	87·1794	87·4412	87·7030
28	87·9648	88·2266	88·4884	89·7502	89·0120	89·2738	89·5356	89·7974	90·0592	90·3210	90·5828	90·8446
29	91·1064	91·3682	91·6300	91·8918	92·1536	92·4154	92·6772	92·9390	93·2008	93·4626	93·7244	93·9862
30	94·2480	94·5098	94·7716	95·0334	95·2952	95·5570	95·8186	96·0806	96·3424	96·6042	96·8660	97·1278
31	97·3896	97·6514	97·9132	98·1750	98·4368	98·6986	98·9604	99·2222	99·4840	99·7458	100·008	100·269
32	100·531	100·793	101·055	101·317	101·578	101·840	102·102	102·364	102·626	102·887	103·149	103·411
33	103·673	103·935	104·196	104·458	104·720	104·982	105·244	105·505	105·767	106·029	106·291	106·253
34	106·814	107·076	107·338	107·600	107·862	108·123	108·385	108·647	108·909	109·171	109·432	109·694
35	109·956	110·218	110·480	110·741	111·003	111·265	111·527	111·789	112·050	112·312	112·574	112·836
36	113·098	113·359	113·621	113·883	114·145	114·407	114·668	114·930	115·192	115·454	115·776	115·977
37	116·239	116·501	116·763	117·025	117·286	117·548	117·810	118·072	118·334	118·595	118·857	119·119
38	119·381	119·648	119·904	120·166	120·428	120·690	120·952	121·213	121·475	121·737	121·999	122·261
39	122·522	122·784	123·046	123·308	123·570	123·821	124·093	124·355	124·617	124·879	125·140	125·402

Areas of Circles adancing by 12ths.

Areas.

Diam.	0	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	9/12	10/12	11/12
0	·0000	·0055	·0218	·0491	·0873	·1364	·1963	·2673	·3491	·4418	·5454	·6600
1	·7854	·9218	1·0690	1·2272	1·3963	1·5763	1·7671	1·9689	2·1817	2·4053	2·6398	2·8852
2	3·1416	3·4088	3·6870	3·9761	4·2761	4·5869	4·9087	5·2414	5·5851	5·9396	6·3050	6·6813
3	7·0686	7·4666	7·8758	8·2958	8·7266	9·1684	9·6211	10·0847	10·5592	11·0447	11·5410	12·0482
4	12·5664	13·0954	13·6354	14·1863	14·7480	15·3207	15·9043	16·4988	17·1042	17·7205	18·3478	18·9859
5	19·6350	20·2949	20·9658	21·6475	22·3402	23·0438	23·7583	24·4837	25·2200	25·9672	26·7254	27·4944
6	28·2743	29·0652	29·8669	30·6796	31·5032	32·3377	33·1831	34·0394	34·9066	35·7847	36·6737	37·5737
7	38·4846	39·4063	40·3389	41·2825	42·2370	43·2024	44·1786	45·1658	46·1640	47·1730	48·1929	49·2237

Areas of Circles advancing by 12ths. (concluded).

Diam.	0	$\frac{1}{12}$	$\frac{2}{12}$	$\frac{3}{12}$	$\frac{4}{12}$	$\frac{5}{12}$	$\frac{6}{12}$	$\frac{7}{12}$	$\frac{8}{12}$	$\frac{9}{12}$	$\frac{10}{12}$	$\frac{11}{12}$
	Areas.											
8	50·2655	51·3181	52·3817	53·4562	54·5415	55·6378	56·7450	57·8631	58·9921	60·1320	61·2829	62·4446
9	63·6173	64·8008	65·9953	67·2006	68·4169	69·6441	70·8822	72·1312	73·3911	74·6619	75·9436	77·2363
10	78·5398	79·8543	81·1796	82·5159	83·8631	85·2212	86·5901	87·9700	89·3609	90·7626	92·1752	93·5987
11	95·0332	96·4785	97·9348	99·4020	100·880	102·369	103·869	105·380	106·901	108·434	109·978	111·532
12	113·097	114·676	116·261	117·859	119·468	121·088	122·719	124·360	126·013	127·676	129·351	131·036
13	132·732	134·439	136·158	137·887	139·626	141·377	143·139	144·911	146·695	148·489	150·295	152·111
14	153·938	155·776	157·625	159·485	161·356	163·237	165·130	167·034	168·948	170·873	172·809	174·757
15	176·715	178·684	180·[illegible]63	182·654	186·656	187·663	188·692	190·726	192·772	194·828	196·895	198·973
16	201·062	203·162	205·273	207·394	209·527	211·670	213·825	215·990	218·166	220·353	222·551	224·760
17	226·980	229·211	231·453	233·705	235·969	238·243	240·528	242·824	245·132	247·450	249·778	252·118
18	254·469	256·831	259·203	261·587	263·981	266·386	268·803	271·230	273·668	276·117	278·576	281·047
19	283·529	286·021	288·525	291·039	293·564	296·111	298·648	301·206	303·775	306·354	308·945	311·547
20	314·159	316·783	319·417	322·062	324·719	327·386	330·064	332·753	335·452	338·163	340·885	343·617
21	346·361	349·115	351·880	354·656	357·443	360·241	363·050	365·870	368·701	371·542	374·395	377·258
22	380·133	383·018	385·914	388·821	391·739	394·668	397·608	400·559	403·520	406·493	409·476	412·470
23	415·476	418·492	421·519	424·557	427·606	430·685	433·736	436·818	439·910	443·014	446·128	449·253
24	452·389	455·536	458·694	461·863	465·043	468·234	471·435	474·648	477·871	481·106	484·351	487·307
25	490·874	494·152	497·441	500·740	504·051	507·373	510·705	514·049	517·403	520·768	524·144	527·531
26	530·929	534·338	537·758	541·188	544·630	548·083	551·546	555·020	558·505	562·002	565·509	569·026
27	572·555	576·095	579·646	583·207	586·780	590·363	593·957	597·563	601·179	604·806	608·444	612·092
28	615·752	619·423	623·104	626·797	630·500	634·215	637·940	641·676	645·423	649·181	652·950	656·729
29	660·520	664·321	668·134	671·957	675·792	679·637	683·493	687·360	691·238	695·127	699·026	702·937
30	706·860	710·791	714·734	718·688	722·654	726·630	730·617	734·615	738·623	742·643	746·674	750·715
31	754·768	758·831	762·905	766·990	771·087	775·193	779·311	783·440	787·580	791·730	795·892	800·064
32	804·248	808·442	812·647	816·863	821·090	825·328	829·577	833·837	838·107	842·389	846·681	850·984
33	855·299	85[illegible]·624	863·96[illegible]	868·307	872·665	877·033	881·413	885·804	890·205	894·041	899·041	903·475

Annuity Table.

Showing the Amount to which an Annuity of Re. 1 accumulating at Compound Interest will amount in from 1—50 years at various rates.

No. of Years.	3 per cent.	3½ per cent.	4 per cent.	4½ per cent.	5 per cent.	6 per cent.
1	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
2	2·03000	2·03500	2·04000	2·04500	2·05000	2·06000
3	3·09090	3·10622	3·12160	3·13702	3·15250	3·18360
4	4·18362	4·21494	4·24646	4·27819	4·30012	4·37461
5	5·30913	5·36246	5·41632	5·47070	5·52563	5·63709
6	6·46840	6·55015	6·63297	6·71689	6·80191	6·97531
7	7·66246	7·77940	7·89829	8·01915	8·14200	8·39383
8	8·89233	9·05168	9·21422	9·38001	9·54910	9·89746
9	10·15910	10·36849	10·58279	10·80211	11·02656	11·49131
10	11·46387	11·73139	12·00610	12·28820	12·57789	13·18079
11	12·80779	13·14199	13·48635	13·84117	14·20678	14·97164
12	14·19202	14·60196	15·02580	15·46403	15·91712	16·86994
13	15·61779	16·11303	16·62683	17·15991	17·71298	18·88213
14	17·08632	17·67698	18·29191	18·93210	19·59863	21·01506
15	18·59891	19·29568	20·02358	20·78405	21·57857	23·27596
16	20·15688	20·97102	21·82453	22·71933	23·65749	25·67252
17	21·76158	22·70501	23·69751	24·74170	25·84036	28·21287
18	23·41443	24·49969	25·64541	26·85508	28·13238	30·90565
19	25·11686	26·35718	27·67122	29·06356	30·53900	33·75999
20	26·87037	28·27968	29·77807	31·37142	33·06595	36·78559
21	28·67648	30·26947	31·96920	33·78313	35·71925	39·99272
22	30·53678	32·32890	34·24796	36·30337	38·50521	43·39229
23	32·45288	34·46041	36·61788	38·93702	41·43047	46·99582
24	34·42647	36·66652	39·08260	41·68919	44·50199	50·81557
25	36·45926	38·94985	41·64590	44·56521	47·72709	54·86451
26	38·55304	41·31310	44·31174	47·57065	51·11345	59·15638
27	40·70963	43·75906	47·08421	50·71132	54·66912	63·70576

ANNUITY TABLE—*concluded.*

Showing the Amount to which an Annuity of Re. 1 accumulating at Compound Interest will amount in from 1—50 years at various rates—*concluded.*

No. of Years.	3 per cent.	3½ per cent.	4 per cent.	4½ per cent.	5 per cent.	6 per cent.
28	42·93092	46·29062	49·96758	53·99333	58·40258	68·52811
29	45·21885	48·91079	52·96628	57·42303	62·32271	73·63979
30	47·57541	51·62267	56·08493	61·00706	66·43884	79·05818
31	50·00267	54·42947	59·32833	64·75238	70·76078	84·80167
32	52·50275	57·33450	62·70146	68·66624	75·29882	90·88977
33	55·07784	60·34121	66·20952	72·75620	80·06377	97·34316
34	57·73017	63·45315	69·85790	77·03025	85·06695	104·18375
35	60·46201	66·67401	73·65222	81·49661	90·32030	111·43477
36	63·27594	70·00760	77·59831	86·16396	95·83632	119·12086
37	66·17422	73·45786	81·70224	91·04134	101·62813	127·26811
38	69·15944	77·02889	85·97033	96·13820	107·70954	135·90420
39	72·23423	80·72490	90·40914	101·46442	114·09502	145·05845
40	75·40125	84·55027	95·02551	107·03032	120·79977	154·76196
41	78·66329	88·50953	99·82653	112·84668	127·83976	165·04768
42	82·02319	92·60737	104·81959	118·92478	135·23175	175·95054
43	85·48389	96·84862	110·01238	125·27640	142·99333	187·50753
44	89·04840	101·23833	115·41287	131·91384	151·14300	199·75807
45	92·71986	105·78167	121·02939	138·84996	159·70015	212·74351
46	96·50145	110·48403	126·87056	146·09821	168·68516	226·50812
47	100·39650	115·35097	132·94539	153·67263	178·11942	241·09861
48	104·40839	120·38825	139·26320	161·58790	188·02539	256·56452
49	108·54064	125·60184	145·83373	169·85935	198·42666	272·95840
50	112·79686	130·99791	152·60708	178·50302	209·34799	290·33590

Compound Interest Table.

Showing the sum to which Re. 1 will increase at *Compound Interest* during any number of years not exceeding 50 (compounded yearly).

	2½ per cent.	per cent	4 per cent	5 per cent	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
	1·02500	1·03000(	1·040000	1·050000	1·060000	1·07(	·080	1·090	1·100
	1·05063	1·06090(	1·081600	1·102500	1·123600	1·145	·164	1·188	1·210
	1·07689	1·092727	1·124864	1·15762	1·191016	1·226	·260	1·295	1·330
	1·10381	1·12550(	1·169859	1·215506	1·262477	1·311	·360	1·411	1·464
	1·13141	1·15927	1·21665	1·27628	1·338226	1·403	·469	1·538	1·607
	1·15969	1·194052	1·265319	1·340096	1·418519	1·501	·586	1·67	1·772
	1·18869	1·22987	1·315932	1·407100	1·503630	1·606	1·713	1·827	1·949
8	1·21840	1·26677(	1·36856(	1·477455	1·593848	1·719	1·850	1·992	2·144
9	1·24886	1·30477	1·423312	1·551328	1·689479	1·840	1·998	2·171	2·353
10	1·28008	1·343916	1·480244	1·628895	1·790848	1·968	2·158	2·366	2·594
11	1·31209	1·384234	1·539454	1·710339	1·898299	2·106	2·330	2·580	2·854
12	1·34489	1·425761	1·601032	1·795856	2·012196	2·253	2·517	2·910	3·139
13	1·37851	1·468534	1·665074	1·885649	2·132928	2·411	2·718	3·063	3·453
14	1·41297	1·512590	731676	1·979932	2·260904	2·580	2·934	3·339	3·798
15	1·44830	1·557967	800944	2·078928	2·396558	2·761	3·170	3·639	4·178
16	1·48451	1·604706	1·872981	2·182875	2·54035	2·955	3·432	3·9	4·595
17	1·52162	1·652848	1·947901	2·292018	2·692773	3·161	3·697	4·323	5·057
18	1·55966	1·702433	2·025817	2·406619	2·854339	3·383	3·992	4·712	5·562
19	1·59865	1·753506	2·106849	2·526950	3·025600	3·619	4·311	5·136	6·117
20	1·63862	1·806111	2·191123	2·653298	3·207135	3·873	4·656	5·59	6·730
21	1·67958	1·860295	2·278768	2·785963	3·399564	4·144	5·028	6·101	7·752
22	1·7215	1·916103	·369919	2·925261	3·603537	4·432	5·430	6·649	8·143
23	1·76461	1·973587	·464716	3·071524	3·819750	4·744	5·865	7·247	8·958
24	1·80873	2·032794	·563304	3·225100	4·048935	5·077	6·333	7·900	9·854
25	1·85394	2·093778	·665836	3·386355	4·291871	5·433	6·839	8·610	0·840
26	1·90029	2·156591	·772470	3·555673	4·549383	5·813	7·386	9·393	2·48
27	1·94780	2·221289	·883369	3·73[illegible]456	4·822346	6·220	7·977	10·230	3·11

Compound Interest Table.

Showing the sum to which Re. 1 will increase at *Compound Interest* during any number of years not exceeding 50 (compounded yearly)—*concld.*

No. of Yrs.	2½ per cent.	3 per cent.	4 per cent	5 per cent.	6 per cent.	7 pe cent	8 pe cent	9 per cent.	10 per cent.
28	1·99650	2·287928	2 998703	3·920129	5·111687	6·65	86·1	11·150	14·43
29	2·04641	2·356566	3·118651	4·116136	5·418388	7·12	93·0	12·150	15·87
30	2·09757	2·427262	3·243398	4·321942	5·743491	7·6	10·0	13·240	17·46
31	2·15001	2·500080	3·373133	4·538039	6·088101	8·15	10·8	4·43	19·21
32	2·20376	2·575083	3·508059	4·764941	6·453387	8·72	11·7	5·73	21·13
33	2·25885	652335	3·648381	5·003189	6·840590	9·33	12·6	7·15	23·24
34	2·31532	2·731905	·794316	5·253348	7·251025	9·99	13·7	8·69	25·57
35	2·37321	2·813862	3 946089	5·516015	7·686087	10·69	14·7	0·37	28·12
36	2·43254	2·898278	4 103933	5·791816	8·147252	11·44	15·9	·2·20	30·39
37	2·49335	2·985227	4·268090	6·081407	8·636087	12·240	17·21	·4·19	34·02
38	2·55568	3·074783	4·438813	6·385457	9·154252	13·100	18·59	·6·99	37·43
39	2·61957	3·167027	4·616366	6·704751	9·703507	14·020	20·07	8·75	41·17
40	2·68506	3 262038	4·801021	7·039989	10·285718	15·000	21·68	1·33	45·29
41	2·75219	3·359899	4·993061	7·391988	10·902861	15·600	23·41	4·15	49·82
42	2·82100	3·460696	5·192784	7·761588	11·557033	17·170	25·28	·22	54·80
43	2·8915	3·564517	5·400495	8·149667	12·250455	18·380	27·34	·57	62·29
44	2·96381	3·671452	5·616515	8·557150	12·985482	19·660	29·48	4·22	66·31
45	3·03790	3·781596	5·841176	8·985008	13·764611	21·040	31·84	3·19	72·95
46	3·1138	3·895044	6 074823	9·434258	14·590487	22·510	34·39	·53	80·24
47	3·19170	4·011895	6·317816	9·905971	15·465917	24·080	37·14	·25	88·06
48	3·27149	4·132252	6·570528	10·401270	16·393872	25 770	40·11	·40	101·6
49	3·35328	4·256219	6·833349	10·921333	17·377564	26·340	43·31	·09	106·8
50	3·43711	4·383906	7·106683	11·467400	18·420154	29·510	46·47	·13	117·5

A = Amount.
P = Principal.
n = number of years or period.
r = interest on Rs. 1 for a given period.

$$A = P(1+r)^n \text{ and } P = \frac{A}{(1+r)^n}$$

Table of Compound Interest showing the sum to which Re. 1 will increase at compound interest during any number of years not exceeding 50 *(compounded half-yearly).*

No. of years.	3 per cent.	4 per cent.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
1	1·0301	1·0404	1·05063	1·0609	1·0710	1·0816	1·0915	1·1025
2	1·06125	1·0820	1·10381	1·12509	1·1480	1·16986	1·1921	1·2155
3	1·09202	1·1270	1·15969	1·19405	1·2280	1·265319	1·3025	1·3400
4	1·12603	1·1709	1·21840	1·26677	1·3160	1·368569	1·4224	1·4774
5	1·15910	1·2191	1·28008	1·34391	1·4091	1·48024	1·55523	1·6288
6	1·19320	1·2692	1·34489	1·42576	1·5092	1·601032	1·6954	1·7958
7	1·2291	1·3196	1·41297	1·51259	1·6161	1·731676	1·8518	1·9999
8	1·2662	1·3731	1·48451	1·60470	1·7321	1·87298	2·0217	2·1829
9	1·3041	1·4290	1·55966	1·70243	1·8551	2·02581	2·2072	2·4066
10	1·3432	1·4861	1·63862	1·80611	1·9863	2·19112	2·4109	2·6532
11	1·3835	1·5463	1·72157	1·91610	2·1271	2·36991	2·6318	2·9252
12	1·4241	1·6041	1·80873	2·03279	2·2783	2·56330	2·8745	3·2251
13	1·4681	1·6731	1·90029	2·15659	2·4410	2·77247	3·1374	3·5556
14	1·5110	1·7411	1·99650	2·28792	2·6130	2·99870	3·4263	3·9201
15	1·5491	1·8113	2·09757	2·42726	2·7991	3·24339	3·7417	4·3219
16	1·603	1·8351	2·20376	2·57508	2·9971	3·50805	4·0854	4·7649
17	1·6501	2·0063	2·31532	2·73190	3·2117	3·79431	4·4616	5·2533
18	1·7009	2·0413	2·45254	2·89827	3·4391	4·10393	4·8718	5·7918
19	1·7518	2·1226	2·55568	3·07478	3·6837	4·43881	5·3191	6·3854
20	1·8035	2·2086	2·68506	3·26203	3·9451	4·80102	5·8083	7·0399
21	1·8573	2·2971	2·8210	3·46069	4·2253	5·19278	6·3429	7·7615
22	1·9134	2·3914	2·96381	3·67145	4·5251	5·61615	6·9267	8·5571
23	1·9708	2·4861	3·11385	3·89504	4·8466	6·07582	7·5618	9·4342
24	2·0290	2·5873	3·27147	4·13225	5·1917	6·57052	8·2564	10·4012
25	2·0891	2·6925	3·4286	4·3651	5·5592	7·0792	9·0163	11·4674
26	2·152	2·8009	3·6008	4·630	5·954	7·6562	9·8454	12·6632
27	2·2165	2·9148	3·7835	4·9116	6·3772	8·2991	10·7551	12·7361

Table of Compound interest showing the sum to which Re. 1 *will increase at compound Interest during any number of years not exceeding* 50 *(compounded half-yearly)*—concluded.

No. of years.	3 per cent.	4 per cent.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
28	2·2827	3·0319	3·7745	5·2109	6·8291	8·7546	11·7309	15·3918
29	2·3517	3·1545	4·1746	5·5263	7·3145	9·6836	12·8119	16·9634
30	2·4215	3·2819	4·3854	5·8618	7·8345	10·4761	14·0091	18·7174
31	2·4945	3·4145	4·596	6·2163	8·3908	11·3265	15·2909	20·6365
32	2·5690	3·5518	4·8419	6·5954	8·9863	12·245	16·6908	22·7454
33	2·6381	3·6954	5·0845	6·9954	9·6251	13·246	18·2375	25·0729
34	2·7245	3·8445	5·3409	7·4208	10·3061	14·328	19·9095	27·6541
35	2·8050	3·9991	5·6109	7·8708	11·0285	15·497	21·7362	30·4818
36	2·8895	4·1619	5·8936	8·3462	11·826	16·750	23·7275	33·6091
37	2·9751	4·3291	6·1918	8·8554	12·6671	18·409	25·9036	37·0545
38	3·0653	4·5045	6·4891	9·3936	13·5661	19·5961	28·8025	40·8546
39	3·1561	4·6863	6·8327	9·9654	14·5372	21·1875	30·8919	45·0451
40	3·2514	4·8753	7·1781	10·5721	15·5663	22·9175	33·7327	49·6633
41	3·3481	5·0726	7·5418	11·2165	16·6661	24·7716	36·8316	54·7455
42	3·4492	5·2535	7·9217	11·9081	17·8451	26·7917	40·2231	60·3741
43	3·5517	5·4918	8·3226	12·6175	19·1271	28·9765	43·9128	66·5091
44	3·6581	5·7127	8·7463	13·3831	20·4781	31·3354	47·9517	73·3819
45	3·7672	5·9708	9·1836	14·1917	21·9354	33·8854	52·3635	80·9181
46	3·8809	6·1835	9·6472	15·0591	23·4851	36·6458	57·1841	89·2165
47	3·9975	6·4334	10·1402	15·9765	25·1591	39·6372	62·3451	98·3541
48	4·1156	6·6917	10·6408	16·9370	26·9372	42·8542	68·1601	108·541
49	4·2385	6·9635	11·1907	17·9209	28·8654	46·3454	74·4441	119·551
50	4·3654	7·2445	11·7509	19·0591	30·9087	50·1291	81·281	131·810

Table of Daily pay or allowance from 1 Rupee to 2,000 for a month of

ary per onth.	28			29			30			31			y p. nth.	28			29			30			31 days.		
1	0	0	7	0	0		0	0	6	0	0	6	90	3	3	5	3	1		3	0	0	2	14	5
2	0	1	2	0	1	1	0	1	1	0	1	0	95	3	6	3	3	4	5	3	2	8	3	1	0
	0	1	9	0	1		0	1	7	0	1	7	100	3	9	2	3	7	2	3	5	4	3	3	7
	0	2	3	0	2	2	0	2	2	0	2	1	150	5	5	9	5	2	9	5	0	0	4	13	5
5	0	2	10	0	2	9	0	2	8	0	2	7	200	7	2	3	6	14	4	6	10	8	6	7	3
6	0	3	5	0	3	4	0	3	2	0	3	1	250	8	14	10	8	9	11	8	5		8	1	0
7	0	4	0	0	3	10	0	3	9	0	3	7	300	10	11	5	10	5	6	0	0	0	9	10	10
8	0	4	7	0	4	5	0	4	3	0	4	2	350	12	8	0	12	1	1	11	10	8	11	4	8
9		5	2	0	5	0	0	4	10	0	4	8	400	14			13	12			5	4	12	14	
10		5	9	0		6	0	5	4	0			450	16		2	15	8			0	0	14	8	
15	0	8	7	0	8	3	0	8	0	0	7		500	17		9	17	3	10	16	10	8	16	2	
20	0	11	5	0	11	0	0	10	8	0	10	4	550	19	10	3	18	15	5	18	5	4	17	11	10
25	0	14	3	0	13	10	0	13	4	0	12	11	600	21	6	10	20	11	0	20	0	0	19	5	
30	1	1	2	1	0	7	1	0	0	0	15	6	650	23	3	5	22	6	7	21	10	8	20	15	
35	1	4	0	1	3	4	1	2		1	2	1	700	25	0	0	24	2	2	23		4	22	9	3
40	1	6	10	1	6	1	1			1	4	8	750	26	12	7	25	13	10	25		0	24	3	1
45	1	9	9	1	8	10	1	8		1	7	3	800	28	9	2	27		5	26	10	8	25	12	11
50	1	12	7	1	11	7	1	10		1	9	10	850	30	5	9	29		0	28	5	4	27	6	9
55	1	15	5	1	14	4	1	13	4	1	12		900	32	2	3	31	0	7	30	0	0	29	0	
60	2	2	3	2	1	1	2	0	0	1	15		950	33	14	10	32	2	1	31	10	4	30	10	
65	2	5	2	2	3	10	2	2	8	2	1	7	1000	35	11	5	34	7	9	33	5	4	32	4	2
70	2	8	0	2	6	7	2	5	4	2	4	2	1250	44	10	3	43	1	8	41	10	8	40	5	2
75	2	10	10	2	9	5	2	8	0	2	6	9	1500	53	9	2	51	11	7	50	0	0	48	6	2
80	2	13	9	2	12	2	2	10		2	9	3	1750	62		0	60	5	6	58	5	4	56		
85	3	0	7	2	14	11	2	13		2	11	10	2000	71		0	68	15	5	66	10	8	64		

Table of Exchange giving value of £1 in Rupees at different rates of exchange from 1s. 3d. to 1s. 9d. advancing by $\frac{1}{32}$nd.

Exchange.		Rupees.			Exchange.		Rupees.			Exchange.		Rupees.			Exchange.		Rupees.		
Sh.	d.	Rs.	A.	P.	Sh.	d.	Rs.	a.	p	Sh.	d.	Rs.	a.	p.	Sh.	d.	Rs.	a.	p.
1	3	16	0	0	1	$3\frac{25}{32}$	15	3		1	$4\frac{18}{32}$	14	7	10	1	$5\frac{11}{32}$	13	13	4
1	$3\frac{1}{32}$	15	15	5	1	$3\frac{26}{32}$	15	2	1	1	$4\frac{19}{32}$	14	7	4	1	$5\frac{12}{32}$	3	13	0
1	$3\frac{2}{32}$	15	14	11		$3\frac{27}{32}$	15	2			$4\frac{20}{32}$	14	6	11	1	$5\frac{13}{32}$	13	12	7
1	$3\frac{3}{32}$	15	14	4		$3\frac{2}{3}$	15	1	1		$4\frac{21}{32}$	14	6	6	1	$5\frac{14}{32}$	3	12	2
1	$3\frac{4}{32}$	15	13	10	1	$3\frac{29}{32}$	15	1			$4\frac{22}{32}$	14	6	1		$5\frac{15}{32}$	13	11	9
1	$3\frac{5}{32}$	15	13	4	1	$3\frac{30}{32}$	15	0	1		$4\frac{23}{32}$	.4	5	8		$5\frac{16}{32}$	13	11	5
1	$3\frac{6}{32}$	15	12	10	1	$3\frac{31}{32}$	5	0			$4\frac{24}{32}$	4	5	3		$5\frac{17}{32}$	13	11	0
1	$3\frac{7}{32}$	15	12	3	1	4	15	0			$4\frac{25}{32}$	4	4	9		$5\frac{18}{32}$	13	10	7
	$3\frac{8}{32}$					$4\frac{1}{32}$	4	15			$4\frac{26}{32}$	4	4	4	1	$5\frac{19}{32}$	13	10	3
	$3\frac{9}{32}$	15	11	3	1	$4\frac{2}{32}$	4	15			$4\frac{27}{32}$	4	3	11	1	$5\frac{20}{32}$	13	9	10
	$3\frac{10}{32}$	15	10	[illegible]	1	$4\frac{3}{32}$	4	14			$4\frac{28}{32}$	4	3	6		$5\frac{21}{32}$	13	9	5
	$3\frac{11}{32}$	15	10	6	[illegible]	$4\frac{4}{32}$	4	14				4	3	1			13	9	1
	$3\frac{12}{32}$	15	9	9		$4\frac{5}{32}$	4	13			$4\frac{30}{32}$	14	2		1	$5\frac{23}{32}$	13	8	8
	$3\frac{13}{32}$	15	9	2		$4\frac{6}{32}$	4	13			$4\frac{31}{32}$	14	2		1	$5\frac{24}{32}$	13	8	4
	$3\frac{14}{32}$	15	8	8		$4\frac{7}{32}$	4	12		1	5	14	1	10	1	$5\frac{25}{32}$	13	7	11
	$3\frac{15}{32}$	15	8	0		$4\frac{8}{32}$	4	12		1	$5\frac{1}{32}$	14	1	5	1	$5\frac{26}{32}$	13	7	6
1	$3\frac{16}{32}$	15	7	8	1	$4\frac{9}{32}$	4	11	10	1	$5\frac{2}{32}$	14	1	0	1	$5\frac{27}{32}$	3	7	2
1	$3\frac{17}{32}$	15	7		1	$4\frac{10}{32}$	4	11	4	1	$5\frac{3}{32}$	14	0		1	$5\frac{28}{32}$	3	6	9
1	$3\frac{18}{32}$	15	6	8	1	$4\frac{11}{32}$	4	10	11	1	$5\frac{4}{32}$	4	0		1	$5\frac{29}{32}$	3	6	5
1	$3\frac{19}{32}$	15	6	3	1	$4\frac{12}{32}$	4	10	6	1	$5\frac{5}{32}$	3	15	9	1	$5\frac{30}{32}$	3	6	0
1	$3\frac{20}{32}$	10	5	9	1	$4\frac{13}{32}$	4	10	9		$5\frac{6}{32}$	3	15		1	$5\frac{31}{32}$	3	5	8
1	$3\frac{21}{32}$	5	5	3	1	$4\frac{14}{32}$	4	9	7		$5\frac{7}{32}$	13	15	0	1	6	3	5	4
1	$3\frac{22}{32}$	5	4	9	1	$4\frac{15}{32}$	14	9	2		$5\frac{8}{32}$	13	4	7					
1	$3\frac{23}{32}$	.5	4	3	1	$4\frac{16}{32}$	14	8	8		$5\frac{9}{32}$	13	14	2					
1	$3\frac{24}{32}$	.5	8	9	1	$4\frac{17}{32}$	14	8	3	1	$5\frac{10}{32}$	13	13	9					

Table of Exchange (Concluded.)

Exchange.		Rupees.			Exchange.		Rupees.			Exchange.		Rupees.			Exchange.		Rupees.		
Sh.	d.	Rs.	a.	p.	Sh.	d.	Rs.	a.	p.	Sh.	d.	Rs.	a.	p.	Sh.	d.	Rs.	a.	p.
1	$6\frac{1}{32}$	13	4	11	1	$6\frac{25}{32}$	12	12	5	1	$7\frac{17}{32}$	12	4	7	1	$8\frac{9}{32}$	11	13	4
1	$6\frac{2}{32}$	13	4	7	1	$6\frac{26}{32}$	12	12	1	1	$7\frac{18}{32}$	12	4	3	1	$8\frac{10}{32}$	11	13	0
1	$6\frac{3}{32}$	13	4	2	1	$6\frac{27}{32}$	12	11	9	1	$7\frac{19}{32}$	12	3	11	1	$8\frac{11}{32}$	11	12	9
1	$6\frac{4}{32}$	13	3	10	1	$6\frac{28}{32}$	12	11	5	1	$7\frac{20}{32}$	12	3	8	1	$8\frac{12}{32}$	11	12	5
1	$6\frac{5}{32}$	13	3	5	1	$6\frac{29}{32}$	12	11	1	1	$7\frac{21}{32}$	12	3	4	1	$8\frac{13}{32}$	11	12	2
1	$6\frac{6}{32}$	13	3	1	1	$6\frac{30}{32}$	12	10	9	1	$7\frac{22}{32}$	12	3	0	1	$8\frac{14}{32}$	11	11	10
1	$6\frac{7}{32}$	13	2	9	1	$6\frac{31}{32}$	12	10	5	1	$7\frac{23}{32}$	12	2	8	1	$8\frac{15}{32}$	11	11	7
1	$6\frac{8}{32}$	13	2	4	1	7	12	10	1	1	$7\frac{24}{32}$	12	2	5	1	$8\frac{16}{32}$	11	11	3
1	$6\frac{9}{32}$	13	2	0	1	$7\frac{1}{32}$	12	9	9	1	$7\frac{25}{32}$	12	2	1	1	$8\frac{17}{32}$	11	11	0
1	$6\frac{10}{32}$	13	1	8	1	$7\frac{2}{32}$	12	9	5	1	$7\frac{26}{32}$	12	1	9	1	$8\frac{18}{32}$	11	10	8
1	$6\frac{11}{32}$	13	1	4	1	$7\frac{3}{32}$	12	9	1	1	$7\frac{27}{32}$	12	1	6	1	$8\frac{19}{32}$	11	10	5
1	$6\frac{12}{32}$	13	0	11	1	$7\frac{4}{32}$	12	8	9	1	$7\frac{28}{32}$	12	1	2	1	$8\frac{20}{32}$	11	10	2
1	$6\frac{13}{32}$	13	0	7	1	$7\frac{5}{32}$	12	8	5	1	$7\frac{29}{32}$	12	0	10	1	$8\frac{21}{32}$	11	9	10
1	$6\frac{14}{32}$	13	0	3	1	$7\frac{6}{32}$	12	8	1	1	$7\frac{30}{32}$	12	0	7	1	$8\frac{22}{32}$	11	9	7
1	$6\frac{15}{32}$	12	15	11	1	$7\frac{7}{32}$	12	7	9	1	$7\frac{31}{32}$	12	0	3	1	$8\frac{23}{32}$	11	9	4
1	$6\frac{16}{32}$	12	15	6	1	$7\frac{8}{32}$	12	7	5	1	8	12	0	0	1	$8\frac{24}{32}$	11	9	0
1	$6\frac{17}{32}$	12	15	2	1	$7\frac{9}{32}$	12	7	1	1	$8\frac{1}{32}$	11	15	8	1	$8\frac{25}{32}$	11	8	9
1	$6\frac{18}{32}$	12	14	10	1	$7\frac{10}{32}$	12	6	10	1	$8\frac{2}{32}$	11	15	4	1	$8\frac{26}{32}$	11	8	6
1	$6\frac{19}{32}$	12	14	6	1	$7\frac{11}{32}$	12	6	6	1	$8\frac{3}{32}$	11	15	1	1	$8\frac{27}{32}$	11	8	2
1	$6\frac{20}{32}$	12	14	2	1	$7\frac{12}{32}$	12	6	2	1	$8\frac{4}{32}$	11	14	9	1	$8\frac{28}{32}$	11	7	11
1	$6\frac{21}{32}$	12	13	9	1	$7\frac{13}{32}$	12	5	10	1	$8\frac{5}{32}$	11	14	6	1	$8\frac{29}{32}$	11	7	8
1	$6\frac{22}{32}$	12	13	5	1	$7\frac{14}{32}$	12	5	6	1	$8\frac{6}{32}$	11	14	2	1	$8\frac{30}{32}$	11	7	4
1	$6\frac{23}{32}$	12	13	1	1	$7\frac{15}{32}$	12	5	2	1	$8\frac{7}{32}$	11	13	11	1	$8\frac{31}{32}$	11	7	1
1	$6\frac{24}{32}$	12	12	9	1	$7\frac{16}{32}$	12	4	11	1	$8\frac{8}{32}$	11	13	7	1	9	11	6	10

WEIGHT AND STRENGTH OF MATERIALS.

SQUARE AND ROUND STEEL.

Weights in Lbs. per Lineal Foot and Areas in Square Inches.

Side or Diameter in inches.	Square. Weight.	Square. Area.	Round. Weight.	Round. Area.	Side or Diameter in inches.	Square. Weight.	Square. Area.	Round. Weight.	Round. Area.
3/16	·120	*·035*	·094	*·027*	4	54·40	*16·00*	42·73	*12·57*
1/4	·213	*·062*	·167	*·049*	4 1/4	61·41	*18·06*	48·23	*14·18*
5/16	·332	*·097*	·261	*·076*	4 1/2	68·85	*20·25*	54·07	*15·90*
3/8	·478	*·140*	·376	*·110*	4 3/4	76·71	*22·56*	60·25	*17·72*
7/16	·651	*·191*	·511	*·150*	5	85·00	*25·00*	66·76	*19·63*
1/2	·849	*·250*	·668	*·196*	5 1/4	93·71	*27·56*	73·60	*21·65*
9/16	1·076	*·316*	·845	*·248*	5 1/2	102·85	*30·25*	80·78	*23·76*
5/8	1·328	*·390*	1·043	*·306*	5 3/4	112·41	*33·06*	88·29	*25·97*
11/16	1·607	*·472*	1·262	*·371*					
3/4	1·912	*·562*	1·502	*·442*	6	122·40	*36·00*	96·13	*28·27*
13/16	2·245	*·660*	1·763	*·518*	6 1/4	132·81	*39·06*	104·31	*30·68*
7/8	2·603	*·765*	2·044	*·601*	6 1/2	143·65	*42·25*	112·82	*33·18*
15/16	2·988	*·879*	2·347	*·690*	6 3/4	154·87	*45·56*	121·67	*35·76*
1	3·400	*1·000*	2·670	*·785*	7	166·60	*49·00*	130·85	*38·48*
1 1/8	4·303	*1·265*	3·380	*·994*	7 1/4	178·70	*52·56*	140·36	*41·28*
1 1/4	5·312	*1·562*	4·192	*1·227*	7 1/2	191·25	*56·25*	150·21	*44·18*
1 3/8	6·428	*1·890*	5·040	*1·485*	7 3/4	204·20	*60·06*	160·39	*47·17*
1 1/2	7·650	*2·250*	6·008	*1·767*	8	217·60	*64·00*	170·90	*50·26*
1 5/8	8·978	*2·640*	7·051	*2·074*	8 1/4	231·40	*68·06*	181·75	*53·45*
1 3/4	10·41	*3·062*	8·178	*2·405*	8 1/2	245·65	*72·25*	192·93	*56·74*
1 7/8	11·95	*3·515*	9·388	*2·761*	8 3/4	260·30	*76·56*	204·45	*60·13*
2	13·60	*4·000*	10·68	*3·141*	9	275·40	*81·00*	216·30	*63·62*
2 1/8	15·35	*4·515*	12·06	*3·546*	9 1/4	290·90	*85·56*	228·48	*67·20*
2 1/4	17·21	*5·062*	13·52	*3·976*	9 1/2	306·85	*90·25*	241·00	*70·88*
2 3/8	19·18	*5·640*	15·06	*4·430*	9 3/4	323·20	*95·06*	253·85	*74·66*
2 1/2	21·25	*6·250*	16·69	*4·908*	10	340·00	*100·00*	267·04	*78·54*
2 5/8	23·43	*6·890*	18·40	*5·412*	10 1/4	357·20	*105·06*	280·55	*82·51*
2 3/4	25·71	*7·562*	20·19	*5·939*	10 1/2	374·85	*110·25*	294·41	*86·59*
2 7/8	28·10	*8·265*	22·07	*6·492*	10 3/4	392·90	*115·56*	308·59	*90·76*
3	30·60	*9·000*	24·03	*7·068*	11	411·40	*121·00*	323·11	*95·03*
3 1/4	35·91	*10·56*	28·21	*8·296*	11 1/2	449·65	*132·25*	353·15	*103·87*
3 1/2	41·65	*12·25*	32·71	*9·621*	12	489·60	*144·00*	384·53	*113·09*
3 3/4	47·81	*14·06*	37·55	*11·04*					

METHOD FOR FINDING THE WEIGHT OF METALS.

Weight of metal in lbs. per yard=(area in sq. inches)×10.

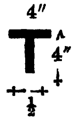
Example :—Find the weight of 1 inch diameter round bar of length one foot.

Area=·7854 sq. inches.

Weight per yard=7·854.

∴ Weight of one foot=7·854÷3=2·618 lbs.

Example (2). Find the weight of one foot length of T iron shown in the sketch.



$Area=(4+4)\times\frac{1}{2}=(\frac{1}{2})^2=4-\frac{1}{4}=3\cdot75$ sq. inches.

Weight per yard=37·5 lbs.

„ per foot=12·5 lbs.

Example (3). Find the weight of sheet iron ½ inch thick.

Area of 1 foot length=12′×½=6 sq. inches.

Weight per yard=60 lbs.

Weight per foot=20 lbs.

In order to find the weight of other metals multiply the weight of iron by the following :—

For	Tin.	Zinc.	Lead.	Brass.	Copper.	Steel.	Aluminium.
	·94	·92	1·47	1·09	1·15	1·02	·34

METHOD OF FINDING THE WEIGHT OF A PIPE.

Let D=internal diameter in inches.

d=thickness of pipe in inches

then the weight in lbs. for

Cast iron pipe per running foot $=(D+d)\times d\times 9\cdot8$.

Wrought iron „ „ „ $=(D+d)\times d\times 10\cdot56$.

Brass „ „ „ „ $=(D+d)\times d\times 11\cdot28$.

Copper „ „ „ „ $=(D+d)\times d\times 12\cdot12$.

Lead „ „ „ „ $=(D+d)\times d\times 15\cdot44$.

WEIGHT OF FLAT ROLLED STEEL IN LBS. PER LINEAL FOOT.

Width in Inches.	Thickness in inches.								
	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
1	·850	1·06	1·28	1·49	1·70	2·13	2·55	2·98	3·40
1¼	1·06	1·33	1·59	1·86	2·13	2·66	3·19	3·72	4·25
1½	1·28	1·59	1·91	2·23	2·55	3·19	3·83	4·46	5·10
1¾	1·49	1·86	2·23	2·60	2·98	3·72	4·46	5·21	5·95
2	1·70	2·13	2·55	2·98	3·40	4·25	5·10	5·95	6·80
2¼	1·91	2·39	2·87	3·35	3·83	4·78	5·74	6·69	7·65
2½	2·13	2·66	3·19	3·72	4·25	5·31	6·38	7·44	8·50
2¾	2·34	2·92	3·51	4·09	4·68	5·84	7·01	8·18	9·35

WEIGHT OF FLAT ROLLED STEEL IN LBS. PER LINEAL FOOT—*concld.*

Width in Inches.	Thickness in Inches.								
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
.. .. 3	2·55	3·19	3·83	4·46	5·10	7·38	7·65	8·93	10·20
.. 3¼ ..	2·76	3·45	4·14	4·83	5·53	6·91	8·29	9·67	11·05
3½	2·98	3·72	4·46	5·21	5·95	7·44	8·93	10·41	11·90
.. 3¾ ..	3·19	3·98	4·78	5·58	6·38	7·97	9·56	11·16	12·75
.. .. 4	3·40	4·25	5·10	5·95	6·80	8·50	10·20	11·90	13·60
.. 4¼ ..	3·61	4·52	5·42	6·32	7·23	9·03	10·84	12·64	14·45
4½	3·83	4·78	5·74	6·69	7·65	9·56	11·48	13·39	15·30
.. 4¾ .	4·04	5·05	6·06	7·07	8·08	10·09	12·11	14·13	16·15
.. .. 5	4·25	5·31	6·38	7·44	8·50	10·63	12·75	14·88	17·00
.. 5¼ ..	4·46	5·58	6·69	7·81	8·93	11·16	13·39	15·62	17·85
5½	4·68	5·84	7 01	8·18	9·35	11·69	14·03	16·36	18·70
.. 5¾ ..	4·89	6·11	7·33	8·55	9·78	12·22	14·66	17·11	19·55
.. .. 6	5·10	6·38	7·65	9·93	10·20	12·75	15·30	17·85	20·40
.. 6¼ ..	5·31	6·64	7·97	9·30	10·63	13·28	15·94	18·59	21·25
6½	5·53	6·91	8·29	9·67	11·05	13·81	16·58	19·34	22·10
.. 6¾ ..	5·74	7·17	8·61	10·04	11·48	14·34	17·21	20·08	22·95
.. .. 7	5·95	7·44	8 93	10·41	11·90	14·88	17·85	20·83	23·80
.. 7¼ ..	6·16	7·70	9·24	10·78	12·33	15·41	18·49	21·57	24·65
7½	6·38	7·97	9·56	11·16	12·75	15·94	19·13	22·31	25·50
.. 7¾ ..	6·59	8·23	9·88	11·53	13·18	16·47	19·76	23·06	26·35
.. .. 8	6·80	8·50	10·20	11·90	13·60	17·00	20·40	23·80	27·20
.. 8¼ ..	7·01	8·77	10·52	12·27	14·03	17·53	21·04	24·54	28·05
8½	7·23	9·03	10·84	12·64	14·45	18·06	21·68	25·29	28·90
.. 8¾ ..	7·44	9·30	11·16	13·02	14·88	18·59	22·31	26·03	29·75
.. .. 9	7·65	9·56	11·48	13·39	15·30	19·13	22·95	26·78	30·60
.. 9¼ ..	7·86	9·83	11·80	13·76	15·73	19·66	23·59	27·52	31·45
9½	8·08	10·09	12·11	14·13	16·15	20·19	24·23	28·26	32·30
.. 9¾ ..	8·29	10·36	12·43	14·50	16·58	20·72	24·86	29·01	33·15
.. .. 10	8·50	10·63	12·75	14·88	17·00	21·25	25·50	29·75	34·00
.. 10¼ ..	8·71	10·89	13·07	15·25	17·43	21·78	26·14	30·49	34·85
10½	8·93	11·16	13·39	15·62	17·85	22·31	26 78	31·24	35·70
.. 10¾ ..	9·14	11·42	13·71	15·99	18·28	22·84	27·41	31·98	36·55
.. .. 11	9·35	11·69	14·03	16·36	18·70	23·38	28·05	32·73	37·40
.. 11¼ ..	9·56	11·95	14 34	16·73	19·13	23·91	28·69	33·47	38·25
11½	9·78	12·22	14 66	17·11	19·55	24·44	29·33	34·21	39·10
.. 11¾ ..	9·99	12·48	14·98	17·48	19·98	24·97	29·96	34·96	39·95
.. .. 12	10·20	12·75	15·30	17·85	20·40	25·50	30·60	35·70	40·80

Weight of octagonal steel bars per foot in lbs.

Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.
1/8	·044	5/16	·275	11/16	1·332	1 1/8	3·568	1 7/8	9·910
		3/8	·396	3/4	1·586	1 1/4	4·405	2	11·276
3/16	·099	7/16	·540	13/16	1·861	1 3/8	5·330	2 1/4	14·271
		1/2	·705	7/8	2·158	1 1/2	6·343	2 1/2	17·618
		9/16	·892	15/16	2·478	1 5/8	7·444	2 3/4	21·318
1/4	·176	5/8	1·101	1	2·819	1 3/4	8·633	3	25·371

Weight of a square foot of plates of different metals in lbs.

Thickness Inches.	Iron.	Steel.	Brass.	Copper.	Lead.	Zinc.	THICKNESS.	
							Inches.	Milimetres.
1/16	2·5	2·6	2·7	2·9	3·7	2·3	·0625	1·59
1/8	5	5·2	5·5	5·8	7·4	4·7	·125	3·17
3/16	7·5	7·8	8·2	8·7	11·1	7·0	·1875	4·76
1/4	10	10·4	11·0	11·6	14·8	9·4	·25	6·35
5/16	12·5	13·0	13·7	14·5	18·5	11·7	·2125	7·94
3/8	15	15·6	16·4	17·2	22·2	14·0	·375	9·52
7/16	17·5	18·2	19·2	20·0	25·9	16·4	·4375	11·11
1/2	20	20·8	21·9	22·9	29·5	18·7	·5	12·7
9/16	22·5	23·4	24·6	25·7	33·2	21·1	·5625	14·29
5/8	25	26·0	27·4	28·6	36·9	23·4	·625	15·87
11/16	27·5	28·6	30·1	31·4	40·6	25·7	·6875	17·46
3/4	30	31·2	32·9	34·3	44·3	28·1	·75	19·05
13/16	32·5	33·8	35·6	37·2	48·0	30·4	·8125	20·64
7/8	35	36·4	38·3	40·0	51·7	32·8	·875	22·22
15/16	37·5	39·0	41·2	42·[illegible]	55·4	35·1	·9375	23·81
1	40	41·6	43·9	45·8	59·1	37·5	1·000	25·4

Weight of a square foot of sheet metal in lb., thickness standard wire gauge.

S.W.G.	Iron.	Steel.	Copper.	Brass.	S.W.G.	Iron.	Steel.	Copper.	Brass.
1	12·00	12·48	13·68	13·11	16	2·56	2·66	2·92	2·80
2	11·04	11·48	12·59	12·06	17	2·24	2·33	2·55	2·45
3	10·08	10·48	11·49	11·01	18	1·92	2·00	2·19	2·10
4	9·28	9·65	10·60	10·14	19	1·60	1·66	1·82	1·75
5	8·48	8·82	9·67	9·26	20	1·44	1·50	1·64	1·57
6	7·68	7·99	8·76	8·39	21	1·28	1·33	1·46	1·40
7	7·04	7·32	8·03	7·69	22	1·12	1·16	1·28	1·22
8	6·40	6·66	7·30	6·99	23	0·96	1·00	1·09	1·05
9	5·76	5·99	6·57	6·29	24	0·88	0·92	1·00	0·95
10	5·12	5·32	5·84	5·59	25	0·80	0·83	0·91	0·87
11	4·64	4·83	5·29	5·07	26	·72	0·75	0·82	0·79
12	4·16	4·33	4·74	4·54	27	·656	·682	·748	·717
13	3·68	3·83	4·20	4·02	28	·592	·616	·675	·647
14	3·20	3·33	3·65	3·50	29	·544	·566	·620	·594
15	2·88	3·00	3·28	3·15	30	·496	·516	·565	·542

Weight of hoop iron per foot in lbs.

Breadth ..	5/8	3/4	7/8	1 in.	1 1/8	1 1/4
B. W. Gauge ..	21	20	19	18	17	16
Weight per lineal foot	·0666	·0875	·1216	·1636	·21	·27
Breadth ..	**1 3/8**	**1 1/2**	**1 3/4**	**2 in.**	**2 1/4**	**2 1/2**
B. W. Gauge ..	15	15	14	13	13	12
Weight per lineal foot	·33	·36	·484	·634	·714	·91

Weight of corrugated iron sheets.

B. W. G.	Size of sheets.	Weight per 100 sq. ft. of roof ready, including lappages.			Square feet per cwt.
	feet.	cwt.	qrs.	lb.	
16 ..	6 × 2 to 8 × 3	3	0	14	40
18 ..	6 × 2 to 8 × 3	2	1	6	50
20 ..	6 × 2 to 8 × 3	1	2	6	62 5
22 ..	6 × 2 to 7 × 2½	1	2	7	77·5
24 ..	6 × 2 to 7 × 2½	1	0	24	94·
26 ..	6 × 2 to 7 × 2½	1	0	6	108·5

NOTE.—(1) Corrugated sheets are usually manufactured 32″ wide and 8′ to 10, long.

The sheets when laid on the roof, overlap 6″ on ends and two corrugations at the sides thus allowing ⅕ for lappage.

All bolts, etc., should be in the ridges and not in the valleys.

In very exposed positions, and particularly with light gauge sheets, wind ties of flat iron or light angle iron are used along the entire length of the roof and held in position by means of purlin hook bolts.

Corrugated iron sheets should not be built into gable and parapets, but should be bent up along the edges.

Deodar is said to destroy zinc, so that galvanized iron should not be laid directly in contact with it.

In localities near the sea or in manufacturing towns, near chemical works, the galvanizing quickly disappears and the sheets become eaten through. In such cases they should be painted or tarred.

WEIGHT OF 100 FEET RUNNING OF CORRUGATED IRON SHEETS IN CWTS.

Reference No.	Corrugations. Width.	Corrugations. Depth.	Corrugations. No.	To cover.	Width. Out to out.	Width. In the flat before corrugating.	Thickness in Standard Wire Gauge. 14	15	16	17
							Cwt.	Cwt.	Cwt.	Cwt.
A	2″	½″	12	2′—0″	2′—1″	2′—5″	..	..	..	..
B	3	¾	8	2—0	2—2	2—5½	..	..	6·229	5·492
C			9	2—3	2—5	2—8¾	..	..	6·916	6·097
D			10	2—6	2—8	3—0	..	..	7·602	6·702
E			11	2—9	2—11	3—3½	..	..	8·341	7·354
F			12	3—0	3—2	3—7⅛	..	..	9·107	8·029
G	4	1	6	2—0	2—2½	2—6½	..	..	6·441	5·678
H			7	2—4	2—6½	2—11	..	..	7·391	6·516
J			8	2—8	2—10½	3—3½	..	..	8·341	7·354
K			9	3—0	3—2½	3—8	..	..	9·291	8·192
L	5	1	5	2—1	2—3½	2—6½	7·966	7·204	6·441	5·678
M			6	2—6	2—8½	3—0	9·402	8·502	7·602	6·702
N			7	2—11	3—1½	3—5½	10·838	9·801	8·763	7·726
P	5	1¼	5	2—1	2—4	2—8½	8·488	7·675	6·863	6·050
Q			6	2—6	2—9	3—2¼	9·990	9·033	8·077	7·124
R			7	2—11	3—2	3—8	11·491	10·391	9·291	8·192
S	5	1½	5	2—1	2—4	2-10	8·880	8·030	7·180	6·330
T			6	2—6	2—9	3—4	10·447	9·447	8·447	7·447
V			7	2—11	3—2	3-10	12·044	10·864	9·714	8·564

WEIGHT OF 100 FEET RUNNING OF CORRUGATED IRON SHEETS IN CWTS.

Thickness in standard wire gauge.								For black or ungalvanized sheets.	Reference No.
18	19	20	21	22	23	24	25		
Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	
..	..	3·586	3·224	2·861	2·499	2·317	2·136	0·324	A
4·796	4·017	3·648	3·279	2·911	2·542	2·358	2·173	·329	B
5·278	4·459	4·050	3·641	3·232	2·822	2·617	2·413	·366	C
5·802	4·902	4·452	4·002	3·552	3·102	2·877	2·652	·402	D
6·367	5·379	4·885	4·391	3·897	3·405	3·157	2·910	·441	E
6·950	5·872	5·333	4·794	4·255	3·745	3·446	3·177	·482	F
4·916	4·153	3·772	3·390	3·009	..	..	..	·341	G
5·641	4·766	4·329	3·891	3·454	..	..	..	·391	H
6·367	5·379	4·885	4·391	3·897	..	..	..	·441	J
7·092	5·992	5·442	4·891	4·341	..	..	..	·491	K
4·916	4·153	3·772	3·390	3·009	..	..	..	·341	L
5·802	4·902	4·452	4·002	3·552	..	..	..	·402	M
6·688	5·651	5·132	4·614	4·095	..	..	..	·463	N
5·238	4·425	5·019	..	..	..	..	..	·363	P
6·165	5·209	4·731	..	..	..	..	..	·427	Q
7·092	5·992	5·442	..	..	..	..	..	·491	R
5·480	4·630	4·205	..	..	..	..	..	·380	S
6·447	5·447	4·947	..	..	..	..	..	·447	T
7·414	6·264	5·689	..	..	..	..	..	·514	V

Corrugated Galvanized Sheets.

(Approximate weight in lbs. per sq. ft.).

Gauge	18	20	22	24	26
Without laps	2·41	1·85	1·55	1·29	·95
With 6 ins. end lap, 1 corrugation side lap.	2·73	2·09	1·75	1·46	1·08
With 6 ins. end lap, 2 corrugations side lap.	3·03	2·33	1·95	1·62	1·19

Note.—Galvanizing is a thin coating of zinc which protects the sheets from the action of atmosphere.

The tables on pages (60-61) give the details of corrugated sheets. Those marked S. P. D. C. and B. are in common use.

GALVANIZED CORRUGATED SHEETS. 32″ WIDE.						GALVANIZED PLAIN SHEETS. 36″ WIDE.			
APPROXIMATE NO. OF SHEETS PER TON.						APPROXIMATE NO. OF SHEETS PER TON.			
Size B.W.G.	6′	7′	8′	9′	10 ft. long.	THICKNESS B.W.G.	Feet long 6.	7	8
16	49	42	37	33	29	16	49	42	37
18	62	53	46	41	37	18	62	53	46
20	79	68	59	53	47	20	79	68	59
22	97	83	73	65	58	22	97	83	73
24	117	100	88	78	70	24	117	100	88
26	155	133	116	103	93	26	155	133	116
28	167	143	125	111	100	28	167	143	125

GALVANIZED ROOF FITTINGS.

WEIGHT OF RIVETS—

$\frac{3}{8}'' \times \frac{1}{4}''$ 57 gross to 1 cwt.

$\frac{1}{2}'' \times \frac{1}{4}''$ 52 „ „

$\frac{5}{8}'' \times \frac{1}{4}''$ 48 „ „

BOLTS AND NUTS—

$1\frac{1}{4}'' \times \frac{1}{4}''$ 24 gross to 1 cwt.

$1\frac{1}{2}'' \times \frac{1}{4}''$ 22 „ „

$\frac{3}{4}'' \times \frac{1}{4}''$ 31 „ „

$\frac{1}{2}'' \times \frac{1}{4}''$ 32 „ „

NAILS—

$2\frac{1}{2}''$ 22 gross to 1 cwt.

10 „ „

SCREWS—

$2\frac{1}{4}''$—24 gross to 1 cwt.

$2\frac{1}{2}''$—21 „ „

$3''$—16 „ „

HOOK BOLTS—

$4'' \times \frac{5}{16}''$—$5\frac{1}{2}$ gross to 1 cwt.

$4\frac{1}{2}'' \times \frac{5}{16}''$—3 „ „

$5'' \times \frac{5}{16}''$—$4\frac{1}{2}$ „ „

$4'' \times \frac{3}{8}''$—4 „ „

$4\frac{1}{2}'' \times \frac{3}{8}''$—$3\frac{1}{2}$ „ „

$5'' \times \frac{3}{8}''$—3 „ „

ROUND WASHERS—

For $\frac{1}{4}''$ Rivets and Nails 57 gross to 1 cwt.

LIMPET WASHERS—

57 gross to 1 cwt.

Tin Sheets.

These are imported from England, packed in boxes, which are numbered. The details of which is shown in the following table :—

IC=Common No. 1. IX=Cross No 1.

IXX=2 Cross No. 1. D C=Common doubles.

DX=Cross doubles. SDC=Small Common doubles.

By carefully looking at the table it will be seen that the increase of one X, increases the weight of the box by 21 lbs. For example, if the weight of IX is 140 lbs., then the weight of IXX will be 161 lbs. and that of IXXX 182 lbs. and so on.

Sheets are of two kinds—

(*a*) Charcoal finish, which is better quality.

(*b*) Coke finish.

Example No. 1 C.

The weight of $30'' \times 20''$ box should not be less than 110 lbs. or more than 114 lbs., and in no case should a single sheet weigh less than 15 ozs. or more than 17 ozs.

List of marks, usual sizes, weights, &c., of tin sheets.

Mark.	Size inches.	No. in a box	Standard Weight. Per box.	Standard Weight. Per sheet.	Mark.	Size inches.	No. in a box.	Standard Weight. Per box.	Standard Weight. Per sheet.
	Inches.		lb.	lb. oz.		Inches.		lb.	lb. oz.
IC			112	0 8	DC			98	1 15⅜
IX			140	0 10	DX			126	2 8¼
IXX	14×10	225	161	0 11½	DXX	17×25	50	147	2 15
IXXX			182	0 13	DXXX			168	3 5¾
IXXXX			203	0 14½	DXXXX			189	3 12½
IC			112	1 0	DC			98	3 14¾
IX			140	1 4	DX			126	5 0⅜
IXX	14×20	112	161	1 7	DXX	34×25	25	147	5 14
IXXX			182	1 10	DXXX			168	6 11½
IXXXX			203	1 13	DXXXX			189	7 9
IC			112	2 0	SDC			168	0 13½
IX			140	2 8	SDX			189	0 15⅙
IXX	28×20	56	161	2 14	SDXX	15×11	200	210	1 0¾
IXXX			182	3 4	SDXXX			231	1 2⅛
IXXXX			203	3 10	SDXXXX			252	1 4⅛
DC			98	0 15¾	SDC			168	1 10⅞
DX			126	1 4⅛	SDX			189	1 14¼
DXX	17×12½	100	147	1 7½	SDXX	15×22	100	210	2 1¾
DXXX			168	1 10⅞	SDXXX			231	2 5
DXXXX			189	1 14¼	SDXXXX			252	2 8¼

Thickness of Sheets.

Mark.	Weight.	S.W.G.	Mark.	Weight.	S.W.G.	Mark	Weight.	S.W.G.
	lb.			lb.			lb.	
IC	·514	30	DC	·664	27	SDC	·733	26
IX	·348	27	DX	·854	24	SDX	·825	25
IXX	·739	26	DXX	·996	23	SDXX	·916	24
IXXX	·836	25	DXXX	1·138	22	SDXXX	1·008	23
IXXXX	·932	23	DXXXX	1·281	21	SDXXXX	1·100	22

Comparative weights of different metals, etc.

	Cast iron.	Wrought iron.	Steel.	Brass.	Gun metal.	Copper.	Lead.	Zinc.	Tin.
Cast iron ..	1	1·05	1·08	1·16	1·21	1·21	1·56	0·99	1·003
Wrought iron	0·95	1	1·02	1·10	1·15	1·15	1·48	0·94	0·95
Steel ..	0·93	0·98	1	1·07	1·11	1·12	1·45	0·92	0·93
Brass ..	0·87	0·92	0·93	1	1·04	1·05	1·35	0·86	0·87
Gun-metal ..	0·84	0·88	0·90	0·96	1	1·01	1·30	0·83	0·84
Copper ..	0·83	0·87	0·89	0·96	0·99	1	1·30	0·81	0·83
Lead ..	0·64	0·68	0·69	0·74	0·77	0·78	1	0·63	0·64
Zinc ..	1·01	1·07	1·09	1·17	1·21	1·22	1·58	1	1·01
Tin	0·99	1·05	1·07	1·15	1·20	1·21	1·55	·98	1

Example.—A wrought iron sheet weighs 700 lbs. Find the weight of similar kind of sheet of gun-metal and lead.

Weight of gun-metal sheet $=700\times1.15=805$ lbs.

Weight of lead metal sheet $=700\times1.5=1{,}050$ lbs.

Useful Data.

A rod of wrought iron { Maximum weight 448 lbs.
  „ length 30 to 35 ft.

Wrought iron angle or T { Maximum width=6 inches.
  „ weight=448 lbs.
  „ length=35 ft.
  Total of depth and width=8½ inches.

Wrought iron sheets { Maximum weight 5 cwt. or 560 lbs.
  „ length =12 ft.
  „ area=48 s. ft.
  „ width=4 ft.

If the dimensions are increased, the cost will be more.

Buckled Plates.

The resistance of square buckled plates bolted or riveted down all round, is double the resistance of the same plate merely supported all round, and if the two opposite sides be wholly unsupported, its resistance is reduced in the proportion of 8 to 5.

The stiffness of buckled plates is as the square of the thickness, and inversely as the curvature.

Two inches curvature suffices for 4 feet square and ¼ inch thick.

Ordinary plates are made 3 feet and 4 feet square.

Weight and Safe Load of Iron Buckled Plates, 3 feet square.

No.	Thickness of Metal.	Weight in Lbs.	Safe Load distributed in Tons.			
			Passive.		*Impulsive.*	
			Per Plate.	Per Sq. Ft.	Per Plate.	Per Sq. Ft.
1	18 B.W.G. ..	17·3	·27	·03	·20	·022
2	16 ..	23·6	·43	·048	·32	·036
3	12 ..	38·7	·64	·071	·48	·053
4	⅛ in. ..	45·0	1·00	·112	·75	·083
5	3/16 " ..	67·5	2·5	·278	1·7	·189
6	¼ " ..	90·0	4·5	·5	3·0	·333
7	5/16 " ..	112·5	6·2	·689	4·7	·522
8	⅜ " ..	135·0	9·0	1·0	6·8	·755

The safe load may be doubled for buckled plates of steel.

GAS TUBING.

Approximate Weight and Sizes.

Nominal Bore, inches ..	¾	1	1¼	1½	2
Thickness S. W. G. ..	11	10	9	8	8
Thickness Inches ..	·116	·128	·144	·160	·160
No. of Threads per inch (Whitworth).	14	11	11	11	11
Weight per foot in lbs. ..	1·18	1·79	2·52	2·97	4·48

Weight of Wrought Iron Gas-tubing often used in water-works per 1,000 lineal feet.

Bore.	Weight.	Bore.	Weight.	Bore.	Weight.
Inches.	Cwt.	Inches.	Cwt.	Inches.	Cwt.
$\frac{1}{8}$	2·5	1	16·0	$2\frac{1}{4}$	47·5
$\frac{1}{4}$	3·66	$1\frac{1}{4}$	22·5	$2\frac{1}{2}$	59·6
$\frac{3}{8}$	5·41	$1\frac{1}{2}$	26·5	$2\frac{3}{4}$	75·0
$\frac{1}{2}$	7·77	$1\frac{3}{4}$	35·0	3	82·5
$\frac{3}{4}$	10·5	2	40·0		

Weight of Cast Iron Pipes in lbs. per lineal foot.

Note.—Weight of two flanges may be taken = weight of one foot.

Bore, Inches.	Thickness of Metal.							
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
2	8·7	12·3	16·1	20·8	24·8	..	..	..
3	12·4	17·1	22·2	29·4	33·4	..	..	..
4	16·4	22·1	28·3	35·1	42·0	..	..	..
5	19·8	26·9	34·4	42·3	50·6	..	..	..
6	23·4	31·9	40·6	49·7	59·2	..	..	..
7	27·1	36·8	46·7	56·8	67·8	..	..	..
8	30·8	41·6	52·8	64·3	76·4	..	..	..
9	34·4	46·0	58·9	71·7	85·1	..	..	..
10	38·3	51·4	65·1	79·0	93·3	..	..	..
11	42·0	56·4	71·0	86·4	101·8	..	..	..
12	45·7	61·5	77·3	93·7	110·4	127·4	..	..
14	53·1	74·4	89·6	108·4	127·6	147·0	..	..
15	56·7	76·3	96·1	115·7	136·1	156·8	177·7	..
16	60·4	81·2	102	128·1	144·7	166·6	188·7	..
18	67·8	91·0	115	137·9	161·8	186·2	210·8	..
20	75·2	101	127	153	178·9	205·8	232·9	260·3
22	82·6	111	139	168	..	225·4	254·9	284·8
24	89·9	121	152	183	..	245·0	276·9	309·3

Weight of 9 feet lengths of flanged cast iron pipes.

Pipe.		Flange.		Diameter of circle through hole.	Holes.		Weight.		
Bore	Thickness.	Diameter	Thickness.		Diameter.	No.			
In.	In.	In.	In.	In.	In.		cwt.	qrs.	lbs.
2	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	4	0	3	0
3	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{5}{8}$	6	$\frac{5}{8}$	4	1	0	3
4	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	$7\frac{3}{4}$	$\frac{5}{8}$	4	1	3	5
5	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	$8\frac{3}{8}$	$\frac{3}{4}$	4	2	1	12
6	$\frac{5}{8}$	12	$\frac{1}{8}$	10	$\frac{7}{8}$	4	3	2	1
7	$\frac{5}{8}$	14	1	$11\frac{3}{4}$	$\frac{3}{4}$	6	4	3	17
8	$\frac{3}{4}$	15	1	$12\frac{3}{4}$	1	6	5	2	9
9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	$14\frac{1}{4}$	1	6	6	1	12
10	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	$15\frac{1}{2}$	1	6	7	0	0
11	$\frac{7}{8}$	19	$1\frac{3}{16}$	$16\frac{3}{4}$	1	6	8	3	24
12	$\frac{7}{8}$	20	$1\frac{1}{4}$	$17\frac{3}{4}$	$1\frac{1}{8}$	6	9	3	5
13	$\frac{7}{8}$	21	$1\frac{1}{4}$	$18\frac{3}{4}$	$1\frac{1}{8}$	6	10	2	0
14	$\frac{7}{8}$	22	$1\frac{1}{4}$	$19\frac{3}{4}$	$1\frac{1}{8}$	8	11	0	26
15	$\frac{7}{8}$	23	$1\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{1}{8}$	8	12	0	28
16	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	22	$1\frac{1}{4}$	8	12	3	5
17	$\frac{7}{8}$	$25\frac{1}{2}$	$1\frac{5}{16}$	23	$1\frac{1}{4}$	8	13	2	17
18	1	$26\frac{1}{2}$	$1\frac{3}{8}$	24	$1\frac{1}{4}$	8	16	1	15
19	1	28	$1\frac{3}{8}$	25	$1\frac{3}{8}$	8	17	2	13
20	1	29	$1\frac{3}{8}$	26	$1\frac{3}{8}$	8	18	0	26

Note.—Let t=thickness of pipe in inches.
H=Head of water in ft.
d=diameter of pipe in inches.

$$\text{then } t = .25 + \frac{Hd}{9600}$$

Weight of lead required for jointing cast iron pipes.

Diameter of pipe.	Thickness of lead.	Depth of finished joint.	Weight of lead per joint.	Diameter of pipe.	Thickness of lead.	Depth of finished joint.	Weight of lead per joint.
In.	In.	In.	lb.	In.	In.	In.	lb.
3	$\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	12	$\frac{3}{8}$	$2\frac{1}{8}$	13
4	$\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{4}$	15	$\frac{3}{8}$	$2\frac{1}{4}$	$19\frac{1}{4}$
5	$\frac{3}{8}$	$1\frac{7}{8}$	6	18	$\frac{3}{4}$	$2\frac{3}{8}$	$24\frac{1}{4}$
6	$\frac{3}{8}$	2	$7\frac{1}{2}$	21	$\frac{3}{4}$	$2\frac{3}{8}$	28
8	$\frac{3}{8}$	$2\frac{1}{8}$	10	24	$\frac{3}{8}$	$2\frac{1}{2}$	38

Weight of wrought-iron pipes, per foot run in lb.

Bore.	Thickness of metal in parts of an inch. 1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
Ins.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
¼	·21	·5	·9	1·3	1·9	2·5	3·1	3·9
⅜	·29	·66	1·1	1·6	2·3	3·0	3·8	4·6
½	·37	·83	1·4	2·0	2·7	3·5	4·3	5·3
⅝	·46	1·09	1·6	2·3	3·1	3·9	4·9	5·9
¾	·54	1·15	1·9	2·6	3·5	4·5	5·5	6·6
⅞	·62	1·32	2·1	2·9	3·9	4·9	6·1	7·3
1	·7	1·49	2·4	3·3	4·3	5·5	6·7	7·9
1¼	·87	1·82	2·9	3·9	5·2	6·4	7·8	9·3
1½	1·03	2·14	3·3	4·6	6·0	7·4	9·8	10·6
1¾	1·2	2·5	3·8	5·3	6·8	8·4	10·1	11·9
2	1·36	2·81	4·3	5·9	7·6	9·5	11·3	13·2
2¼	1·53	3·1	4·8	6 6	8·5	10·4	12·4	14·5
2½	1·69	3·47	5·3	7·3	9·3	11·4	13·6	15·9
2¾	1·9	3·8	5·8	7·9	10·1	12·4	14·7	17·2
3	2·02	4·13	6·3	8·6	10·9	13·4	15·9	18·5

Weight of copper pipes, per foot run in lb.

Bore.	Thickness in parts of an inch. 1/16	1/8	3/16	1/4	5/16	3/8	7/16
Ins.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
¼	·23	·56	·99	1·51	2·13	2·83	3·64
½	·42	·94	1·56	2·27	3·07	3·97	4·96
¾	·62	1·33	2·17	3·02	4·02	5·11	6·29
1	·79	1·70	2·66	3·78	4·96	6·24	7·61
1¼	·99	2·08	3·26	4·54	5·91	7·38	8·94
1½	1·15	2·44	3·85	5·29	6·85	8·51	10·26
1¾	1·37	2·84	4·40	6·05	7·80	9·64	11·58
2	1·55	3·22	5·00	6·81	8·75	10·78	12·91
2¼	1·75	3·59	5·53	7·56	9·69	11·92	14·23
2½	1·94	3·97	6·18	8·32	10·64	13·06	15·56
2¾	2·13	4·35	6·[illegible]7	9·08	11·59	14·19	16·88
3	2·31	4·73	7·24	9·84	12·53	15·32	18·21

Weight of brass pipes, per foot run in lb.

Bore.	Thickness in parts of an inch.						
	1/16	1/8	3/16	1/4	5/16	3/8	7/16
Ins.	lb.	lb.	lb.	lb.	lb	lb.	lb.
¼	·22	·53	·94	1·43	2·01	2·68	3·44
½	·40	·89	1·47	2·15	2·91	3·75	4·70
¾	·58	1·25	2·01	2·86	3·80	4·83	5·95
1	·76	1·61	2·55	3·58	4·70	5·92	7·25
1¼	·94	1·96	3·09	4·31	5·64	6·98	9·46
1½	1·12	2·34	3·67	5·01	6·49	8·05	9·71
1¾	1·33	2·66	4·14	5·70	7·36	9·11	10·94
2	1·48	3·04	4·69	6·44	8·27	10·20	12·21
2¼	1·65	3·40	5·23	7·16	9·17	11·27	13·46
2½	1·83	3·75	5·77	7·87	10·06	12·35	14·72
2¾	2·01	4·11	6·31	8·59	10·96	13·42	15·97
3	2·19	4·47	6·84	9·31	11·85	14·69	17·42

Weight of lead pipes in lb. per foot run.

Bore in inches.	Length in feet.	Weight of each length in lb.					
		Common.		*Middling.*		*Strong.*	
		Thick-ness in inches.	lb.	Thick-ness in inches.	lb.	Thick-ness in inches.	b.
½	15	·2	16	·29	22	..	26
¾	15	..	24	..	28	..	36
1	15	·11	30	·15	40	·17	46
1¼	12	..	36	..	44	..	53
1½	12	..	48	..	54	..	70
2	10	·17	56	·21	70	·34	83
2½	10	..	70	..	86	..	100

Seamless brass tubes.

Thickness of metal.

B. W. G.		5	6	7	8	9	10	12	14	16	18	20
Inches.		·220	·208	·180	·165	·148	·134	·109	·083	·065	·049	·035
Outside Diameter.		Weight in lb. per foot run.										
In.	M. M.											
½	12·7	..	..	..	..	..	..	..	..	·32	·26	·19
⅝	15·9	..	..	..	..	..	..	..	..	·42	·32	·24
¾	19·0	..	..	..	..	..	..	..	·64	·51	·40	· 8
⅞	22·2	..	..	..	..	..	..	·97	·76	·61	·46	·34
1	25·4	..	..	..	..	..	..	1·12	·88	·69	·54	·39
1⅛	28·6	..	..	..	..	..	1·55	1·28	1·00	·79	·61	..
1¼	31·7	..	..	..	..	..	1·74	1·44	1·12	·88	·67	..
1⅜	34·6	..	..	..	..	2·11	1·93	1·60	1·24	·98	·75	..
1½	38·1	..	..	..	..	2·32	2·13	1·76	1·36	1·07	·82	..
1⅝	41·3	..	..	..	2·78	2·54	2·32	1·92	1·48	1·17	..	..
1¾	44·4	..	..	..	3·02	2·74	2·52	2·07	1·60	1·26	..	..
1⅞	47·6	..	..	3·54	3·27	2·96	2·71	2·23	1·72	1·36	..	..
2	50·8	..	..	3·80	3·50	3·17	2·91	2·38	1·84	1·45	..	..
2⅛	54·0	..	..	4·07	3·74	3·39	3·10	2·55	1·97	1·55	..	..
2¼	57·1	..	..	4·32	3·98	3·61	3·29	2·71	2·08	1·64	..	..
2⅜	60·3	5·49	5·10	4·58	4·22	3·82	3·49	2·86	2·20	1·73	..	..
2½	63·5	5·81	5·40	4·84	4·45	4·04	3·68	3·02	2·33	1·82	..	..
2⅝	66·7	6·13	5·69	5·10	4·70	4·25	3·88	3·18	2·44	1·92	..	..
2¾	69·3	6·45	5·98	5·37	4·94	4·46	4·07	3·33	2·59	2·01	..	..
2⅞	73·0	6·78	6·28	5·62	5·18	4·67	4·26	3·50	2·69	2·11	..	..
3	76·2	7·09	6·57	5·89	5·41	4·89	4·45	3·65	2·80	2·20	..	..
3¼	82·5	7·72	7·16	6·40	5·89	5·32	4·84	3·97	3·05	2·39	..	..
3½	88·9	8·36	7·75	6·92	6·37	5·75	5·23	4·28	3·29	2·58	..	..
3¾	96·2	9·00	8·34	7·45	6·85	6·17	5·61	4·60	3·52	2·77	..	..
4	101·6	9·63	8·93	7·97	7·32	6·60	6·00	4·91	3·77	2·95	..	..
		1·12	0·96	0·74	0·64	0·50	0·41	0·27	0·16	0·10	0·06	0·03

Note.—The above table is calculated on outside diameter. In case only internal diameter is known add the value of X as shown above in the weight given in the table.

Example.—The wieght of a 3″ pipe per ft. run and 10 B. W. G. is =4·45+·41=4·86 lbs.

Standard steam, gas and water-pipe.

Diameter in Inches.			Thickness in inches.	Length for one cub. ft.	Weight per foot in lb.	Threads per inch of screw.
Internal.	Actual External.	Actual Internal.				
⅛	·405	·27	·068	2513·0	0·24	27
¼	·54	·364	·088	1383·8	0·42	18
⅜	·675	·494	·091	751·2	0·56	18
½	·84	·623	·109	472·4	0·84	14
¾	1·05	·824	·113	270·0	1·12	14
1	1·315	1·048	·134	166·9	1·67	11½
1¼	1·66	1·38	·140	96·25	2·24	11½
1½	1·9	1·611	·145	70·66	2·68	11½
2	2·375	2·067	·154	42·91	3·61	11½
2½	2·875	2·468	·204	30·1	5·74	8
3	3·5	3·067	·217	19·5	7·54	8
3½	4·0	3·548	·226	14·57	9·00	8
4	4·5	4·926	·237	11·31	10·66	8
4½	5·0	4·508	·246	9·02	12·49	8
5	5·563	5·045	·259	7·2	14·50	8
6	6·625	6·065	·280	4·98	18·76	8
7	7·625	7·023	·301	3·72	23·27	8
8	8·625	7·982	·322	2·88	28·18	8
9	9·625	8·937	·344	2·29	33·70	8
10	10·75	10·019	·366	1·82	40·00	8

Spikes, Nails and Tacks.

Wrought spikes.

Length.	Number to a keg of 150 lb.			Length.	Number to a keg of 150 lb.				
	¼″	5/16″	⅜″		¼″	5/16″	⅜″	7/16″	½″
In.	No.	No.	No.	In.	No.	No.	No.	No.	No.
3	2250	..	..	7	1161	662	482	445	306
3½	1890	1208	..	8	..	635	455	384	256
4	1650	1135	..	9	..	573	424	300	240
4½	1464	1064	..	10	..	..	391	270	222
5	1380	930	742	11	..	..	..	249	203
6	1292	868	570	12	..	..	..	236	180

Spikes and Nails.

Standard Steel Wire Nails.						Steel Wire Spikes.			Common Iron Nails.		
		Common.		Finishing.							
Sizes.	Length.	Diameter.	Number per pound.	Diameter.	Number per pound.	Length.	Diameter.	Number per pound.	Size.	Length.	Number per pound.
	In.	In.		In.		In.	In.			In.	
2 *d*	1	·0524	1060	·0453	558	3	·1620	41	2 *d*	1	800
3 *d*	$1\frac{1}{4}$	·0588	640	·0508	913	$3\frac{1}{2}$	·1819	30	3 *d*	$1\frac{1}{4}$	400
4 *d*	$1\frac{1}{2}$	·0720	380	·0508	761	4	·2043	23	4 *d*	$1\frac{1}{2}$	300
5 *d*	$1\frac{3}{4}$	·0764	275	·0571	500	$4\frac{1}{2}$	·2294	17	5 *d*	$1\frac{3}{4}$	200
6 *d*	2	·0808	210	·0641	350	5	·2576	13	6 *d*	2	150
7 *d*	$2\frac{1}{4}$	·0858	160	·0641	315	$5\frac{1}{2}$	·2893	11	7 *d*	$2\frac{1}{4}$	120
8 *d*	$2\frac{1}{2}$	·0935	115	·0720	244	6	·2893	10	8 *d*	$2\frac{1}{2}$	85
9 *d*	$2\frac{3}{4}$	·0963	93	·0720	195	$6\frac{1}{2}$	·2849	$7\frac{1}{2}$	9 *d*	$2\frac{3}{4}$	75
10 *d*	3	·1082	77	·0808	137	7	·2294	7	10 *d*	3	60
12 *d*	$3\frac{1}{4}$	·1144	60	·0808	127	8	·3648	5	12 *d*	$3\frac{1}{4}$	50
16 *d*	$3\frac{1}{2}$	·1285	48	·0907	90	9	·3648	$4\frac{1}{2}$	16 *d*	$3\frac{1}{2}$	40
20 *d*	4	·1620	31	·1019	62	..	..	..	20 *d*	4	20
30 *d*	$4\frac{1}{2}$	·1819	22	..	..	..	..	..	30 *d*	$4\frac{1}{2}$	16
40 *d*	5	·2043	17	..	..	..	..	..	40 *d*	5	14
50 *d*	$5\frac{1}{2}$	·2294	13	..	..	..	..	..	50 *d*	$5\frac{1}{2}$	11
60 *d*	6	·2576	1	..	..	..	..	..	60 *d*	[illegible]	8

Tacks.

Title	Length.	Number per pound.	Title.	Length.	Number per pound.	Title.	Length.	Number per pound.
oz.	In.		oz.	In.		oz.	In.	
1	$\frac{1}{8}$	16000	5	$\frac{1}{2}$	3200	16	$\frac{7}{8}$	1000
$1\frac{1}{2}$	$\frac{5}{16}$	10666	6	$\frac{9}{16}$	·2663	18	$\frac{15}{16}$	888
2	$\frac{1}{4}$	8000	8	$\frac{5}{8}$	2000	20	1	800
$2\frac{1}{2}$	$\frac{5}{16}$	6400	10	$\frac{11}{16}$	1600	22	$1\frac{15}{16}$	727
3	$\frac{3}{8}$	5333	12	$\frac{3}{4}$	1333	24	$1\frac{1}{8}$	666
4	$\frac{7}{16}$	4000	14	$\frac{13}{16}$	1143			

Weight of 100 bolts with square Heads and Nuts in lb.

Length of Shank.	Diameter of bolts in inches.								
	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
Inches.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1½	4·0	7·0	10·5	15·2	22·5	39·5	63·0	..	..
1¾	4·4	7·5	11·3	16·3	23·8	41·6	66·0	..	..
2	4·8	8·0	12·0	17·4	25·2	43·8	69·0	109·0	163
2¼	5·2	8·5	12·8	18·5	26·5	45·8	72·0	113·3	169
2½	5 5	9·0	13·5	19·6	27·8	48·0	75·0	117·5	174
2¾	5·8	9·5	14·3	20·7	29·1	50·1	78·0	121·8	180
3	6·3	10·0	15·0	21·8	30·5	52·3	81·0	126·0	185
3½	7·0	11·0	16·5	24·0	33·1	56·5	87·0	134·0	196
4	7·8	12·0	18·0	26·2	35·8	60·8	93·1	142·5	207
4½	8·5	13·0	19·5	28·4	38·4	65·0	99·1	151·0	218
5	9·3	14·0	21·0	30·6	41·1	69·3	105·2	159·6	229
5½	10·0	15·0	22·5	32·8	43·7	73·5	111·3	168·0	240
6	10·8	16·0	24·0	35·0	46·4	77·8	117·3	176·6	251
6½	..	..	25·5	37·2	49·0	82·0	123·4	185·0	262
7	..	..	27·0	39·4	51·7	86·3	129·4	193·7	273
7½	..	..	28·5	41·6	54·3	90·5	135·0	202·0	284
8	..	..	30·0	43·8	59·6	94·8	141·5	210·7	295
9	..	..	..	46·0	64·9	103·3	153·6	227·8	317
10	..	..	..	48·2	70·2	111·8	165·7	244·8	339
11	..	..	..	50·4	75·5	120·8	177·8	261·9	360
12	..	..	..	52·6	80·8	128·8	189·9	278·9	382
13	..	..	..	..	86·1	137·3	202·0	296·0	404
14	..	..	..	..	91·4	145·8	214·1	313·0	426
15	..	..	..	..	96·7	154·3	226·2	330·1	448
16	..	..	..	..	102·0	162·8	238·3	347·1	470
17	..	..	..	..	107·3	171·0	250·4	364·2	492
18	..	..	..	..	112·6	179·5	262·6	381·2	514
19	..	..	..	..	117·9	188·0	274·7	398·3	536
20	..	..	..	..	123·2	206·5	286·8	415·3	558
Per inch additional.	1·4	2·1	3·1	4·2	5·5	8·5	12·3	16·7	21·8

Example.—To find the weight of 100 bolts whose length=25 inches and diameter one inch.

Weight$=558+21\cdot8\times5=558+109$

$=667$ lbs.

CALCULATED WEIGHTS IN POUNDS OF WHITWORTH'S STANDARD BOLTS AND NUTS.

Hexagonal Head and Nut.

Length of shank in inches.	Diameter of Bolt in inches.										
	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
1	·042	·106	·222	·376	·612	..	..	..	..	..	..
1 1/8	·044	·110	·229	·387	·628	..	..	..	..	..	..
1 1/4	·045	·114	·236	·398	·643	·944	..	..	..	..	..
1 3/8	·047	·118	·243	·408	·659	·965	..	..	..	..	..
1 1/2	·049	·122	·250	·419	·675	·986	1·394	..	..	..	..
1 5/8	·050	·126	·257	·430	·690	1·008	1·421	..	..	..	..
1 3/4	·052	·130	·264	·441	·706	1·029	1·449	1·966	..	..	..
1 7/8	·054	·134	·271	·452	·722	1·050	1·477	2·001	..	..	..
2	·056	·138	·278	·463	·737	1·072	1·505	2·036	2·671	..	..
2 1/4	·059	·145	·292	·484	·769	1·114	1·561	2·107	2·758	..	..
2 1/2	·063	·153	·305	·506	·800	1·157	1·616	2·177	2·845	3·572	..
2 3/4	·065	·161	·319	·528	·831	1·199	1·672	2·247	2·932	3·678	..
3	·069	·169	·333	·549	·862	1·242	1·727	2·318	3·019	3·783	4·766
3 1/4	·071	·177	·347	·571	·894	1·284	1·783	2·388	3·106	3·888	4·891
3 1/2	·075	·185	·361	·593	·925	1·327	1·838	2·459	3·195	3·993	5·016
3 3/4	·079	·192	·375	·615	·956	1·369	1·893	2·529	3·280	4·098	5·142
4	·082	·200	·389	·637	·988	1·412	1·950	2·600	3·367	4·204	5·267
4 1/4	·085	·208	·403	·658	1·019	1·455	2·005	2·670	3·454	4·309	5·392
4 1/2	·089	·216	·417	·680	1·050	1·497	2·061	2·740	3·541	4·414	5·517
4 3/4	·092	·224	·431	·702	1·081	1·540	2·116	2·810	3·627	4·519	5·642
5	·096	·232	·445	·724	1·113	1·583	2·172	2·881	3·714	4·624	5·767
5 1/4	·099	·240	·459	·745	1·144	1·625	2·228	2·952	3·801	4·730	5·893
5 1/2	·103	·247	·472	·767	1·175	1·667	2·283	3·022	3·888	4·835	6·018
5 3/4	·106	·255	·486	·789	1·207	1·710	2·339	3·092	3·975	4·940	6·143
6	·110	·263	·500	·810	1·238	1·753	2·394	3·163	4·062	5·045	6·268
6 1/2	·112	·279	·528	·854	1·300	1·838	2·506	3·305	4·236	5·256	6·518
7	·174	·294	·556	·897	1·363	1·923	2·617	3·444	4·410	5·466	6·769
7 1/2	·130	·310	·584	·941	1·425	2.008	2·728	3·585	4·584	5·676	7·019
8	·138	·326	·612	·984	1·488	2·094	2·839	3·726	4·757	5·887	7·270
8 1/2	..	·341	·639	1·028	1·550	2·179	2·950	3·867	4·931	6·097	7·520
9	..	·357	·667	1·071	1·613	2·264	3·062	4·008	5·105	6·308	7·770
9 1/2	..	..	·695	1·115	1·676	2·349	3·173	4·149	5·279	6·518	8·021
10	..	..	·723	1·158	1·739	2·434	3·284	4·290	5·453	6·728	8·271
	Weight in lbs. of one Nut.										
	·0134	·0345	·0757	·1394	·2164	·3203	·4611	·6379	·8511	1·075	1·391
	Weight in lbs. of Shank per 1 inch of length.										
	·0139	·0313	·0557	·0869	·1252	·1703	·2225	·2817	·3477	·4208	·5007
	Weight in lbs. of Shank per 1 foot of length.										
	·167	·376	·668	1·043	1·502	2·044	2·670	3·380	4·172	5·049	6·008

Weight of Nuts and Bolt Heads in lb.

Diameter of bolt in inches ..	¼	⅜	½	⅝	¾	⅞
Weight of hexagon nut and head ..	·017	·057	·35	·261	·45	·72
Weight of square nut and head ..	·021	·071	·169	·330	·57	·96

Diameter of bolt in inches .		1¼	1½	1¾			3
Weight of hexagon nut and head.	1·07	2·09	3·61	5·7	8·56	17	28·8
Weight of square nut and head	1·35	2·63	4·55	7·2	10·8	21	31·3

Let D=diameter of bolt in inches.

W=weight in lbs. of nuts and bolt heads.

then $W=1{\cdot}07 \times D^3$ for hexagon

and $W=1{\cdot}35 \times D^3$ for square.

Weight per 100 of Square Head of Coach Screws in lb.

Length.	Diameter in inches. ⅜	½	⅝	¾	⅞	1
Inches.	lb.	lb.	lb.	lb.	lb.	lb.
1	6½	..	..	..	..	..
1½	7½	16	..	..	..	..
2	9	17½	32	53	..	..
2½	11	20	35	57	..	..
3	12	23	37	61½	94	128
3½	13	26	41½	66	100	140
4	15	27½	45	70½	105	154
4½	..	29½	51	77	..	..
5	..	31½	54	80	120	168
6	..	..	59	89	145	186
7	..	..	..	99	155	208
8	..	..	..	113	165	228
9	..	..	..	..	176	241
10	..	..	..	..	205	278

Note—Weight of screw is equal to weight of a solid bar, diameter = diameter of screw—depth of thread.

Weight and Strength of Iron Bolts.

Ends Enlarged.		Ends not Enlarged.		Breaking strain.	Ends Enlarged.		Ends not Enlarged.		Breaking strain.
Diam. of shank.	Weight per foot run.	Diam. of shank.	Weight per foot run.		Diam. of shank.	Weight per foot run.	Diam. of shank.	Weight per foot run.	
Inches.	lb.	Ins.	lb.	tons	Ins.	lb.	Ins.	lb.	Tons.
1/8	·0414	..	..	·245	1 3/4	8·10	2·14	12·0	45·7
3/16	·093	..	..	·553	1 13/16	8·69	2·22	12·9	49·0
1/4	·165	·35	·321	·983	1 7/8	9·30	2·30	13·8	52·5
5/16	·258	·43	·452	1·53	1 15/16	9·93	2·38	14·7	56·0
3/8	·372	·50	·654	2·21	2	10·6	2·45	15·7	59·7
7/16	·506	·58	·897	3·00	2 1/8	12·0	2·59	17·5	63·8
1/2	·661	·66	1·14	3·93	2 1/4	13·4	2·73	19·5	71·6
9/16	·837	·73	1·41	4·97	2 3/8	14·9	2·88	21·6	79·7
5/8	1·03	·80	1·67	6·14	2 1/2	16·5	3·02	23·9	88·4
11/16	1·25	·88	2·03	7·42	2 5/8	18·2	3·16	26·1	97·4
3/4	1·49	·96	2·41	8·83	2 3/4	20·0	3·30	28·5	106·9
13/16	1·75	1·04	2·81	10·4	2 7/8	21·9	3·45	31·1	116·8
7/8	2·03	1·12	3·26	12·0	3	23·8	3·60	33·9	127·2
15/16	2·33	1·20	3·77	13·8	3 1/4	27·9	3·86	39·1	141·0
1	2·65	1·27	4·27	15·7	3 1/2	32·4	4·12	44·4	163·6
1 1/16	2·99	1·35	4·77	16·8	3 3/4	37·2	4·41	51·0	187·7
1 1/8	3·35	1·42	5·28	18·9	4	42·3	4·70	57·8	213·6
1 3/16	3·73	1·49	5·81	21·1	4 1/4	47·8	4·98	65·2	227·0
1 1/4	4·13	1·55	6·39	23·3	4 1/2	53·6	5·25	72·9	254·0
1 5/16	4·56	1·64	7·04	25·7	4 3/4	59·7	5·53	80·5	283·5
1 3/8	5·00	1·72	7·74	28·2	5	66·1	5·80	88·1	314·2
1 7/16	5·47	1·80	8·48	30·8	5 1/4	72·9	6·08	97·0	324·7
1 1/2	5·95	1·87	9·20	33·6	5 1/2	80·0	6·36	106	356·4
1 9/16	6·46	1·94	9·88	36·4	5 3/4	87·5	6·63	116	389·5
1 5/8	6·99	2·00	10·6	39·4	6	95·2	6·90	126	424·1
1 11/16	7·53	2·07	11·3	42·5					

Note.—The above table can be used for bolts, tie rods, etc.

Example.—Find the diameter of bolt to withstand a breaking stress of 52·5 tons.

The above table gives for ends enlarged 1 7/8 inches and if ends are not enlarged 2·3 inches.

Example.—Find the diameter of bolts to carry a safe stress of 52·5 tons with a factor of safety 3. Breaking stress $=3\times52{\cdot}5=157{\cdot}5$ tons. The table gives 3 1/2 inches and 4·12 inches.

Whitworth Standard Bolts and Nuts, Safe Load in L

Diam. of Bolt.	Diam. at Bottom of Thread.	Area at Bottom of Thread.	Approximate Safe Load in Lbs. At 4,000 lbs. per Sq. In.	At 5,000 lbs. per Sq. In.	At 6,000 lbs. per Sq. In.	At 7,000 lbs. per Sq. In.	At 8,000 lbs. per Sq. In.	At 9,000 lbs. per Sq. In.
Ins.	Ins.	Sq. Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3/16	0·134	0·014	56	70	84	98	112	126
1/4	0·186	0·027	108	135	162	189	216	243
5/16	0·241	0·046	184	230	276	322	378	414
3/8	0·295	0·068	272	340	408	478	546	614
7/16	0·346	0·094	376	470	504	628	752	846
1/2	0·393	0·121	484	605	726	850	970	1,090
9/16	0·455	0·155	620	775	930	1,085	1,240	1,395
5/8	0·508	0·204	816	1,020	1,224	1,418	1,620	1,824
11/16	0·571	0·256	1,024	1,280	1,536	1,792	2,048	2,304
3/4	0·622	0·304	1,216	1,520	1,824	2,126	2,430	2,734
13/16	0·684	0·367	1,468	1,835	2,202	2,569	2,936	3,303
	0·733	0·422	1,688	2,110	2,532	2,954	3,376	3,800
15/16	0·795	0·496	1,984	2,480	2,976	3,472	3,968	4,464
1	0·840	0·554	2,216	2,770	3,324	3,880	4,430	4,990
1 1/8	0·942	0·697	2,788	3,485	4,182	4,880	5,575	6,270
1 1/4	1·067	0·894	3,576	4,470	5,364	6,250	7,145	8,035
1 3/8	1·162	1·058	4,232	5,290	6,348	7,400	8,455	9,510
1 1/2	1·287	1·299	5,196	6,495	7,794	9,030	10,320	11,610
1 5/8	1·369	1·472	5,888	7,360	8,832	10,290	11,760	13,230
1 3/4	1·494	1·753	7,012	8,765	10,518	12,210	13,950	15,700
1 7/8	1·590	1·986	7,944	9,930	11,916	13,900	15,890	17,875
2	1·720	2·311	9,244	11,555	13,866	16,170	18,480	20,790
	1·930	2·926	11,704	14,630	17,556	20,475	23,400	26,325
	2·180	3·733	14,932	18,665	22,398	26,125	29,855	33,590
2 3/4	2·384	4·464	17,856	22,320	26,784	31,220	35,680	40,140
3	2·634	5·450	21,800	27,250	32,700	38,080	43,520	48,960
3 1/4	2·856	6·402	25,608	32,010	38,412	44,814	51,216	57,618
3 1/2	3·105	7·563	30,252	37,815	45,378	57,940	60,504	68,06[illegible]
3 3/4	3·320	8·673	34,692	43,365	52,038	60,710	69,384	78,057
4	3·573	10·027	40,108	50,135	60,162	70,190	80,216	90,240
4 1/4	3·804	11·365	45,480	56,825	68,190	79,575	90,960	102,305
4 1/2	4·054	12·908	51,632	64,540	77,448	90,356	103,264	116,172
4 3/4	4·284	14·404	57,616	72,020	86,424	100,830	115,232	129,636
5	4·534	16·146	64,584	80,730	98,876	113,020	129,168	145,314
5 1/2	5·012	19·720	78,880	98,600	118,320	138,040	157,760	177,480
6	5·487	23·640	94,560	118,200	141,840	165,200	189,120	212,760

Strength of Lead Pipes.

Bore of pipe (Inches)	½	⅝	¾	1	1¼	1½	1¾	2
Weight of pipe per foot	lb. 1.33	1.47	1.87	2.80	4.33	6.0	6.75	8.0
Safe pressure of water	ft. 232	183	174	161	152	140	122	116

Weight of Angle and Tee Iron in lb., per Lineal Foot.

Breadths of flanges added (inches).	Thickness in fractions of an inch.								
	$\frac{3}{16}$	¼	$\frac{5}{16}$	⅜	$\frac{7}{16}$	½	$\frac{9}{16}$	⅝	$\frac{11}{16}$
2	1·13	1·46	1·76	2·03	..	..	..	..	..
2⅛	1·21	1·56	1·89	2·19	..	..	..	..	..
2¼	1·29	1·67	2·02	2·34	..	..	..	..	..
2⅜	1·37	1·77	2·15	2·50	..	..	..	..	..
2½	1·45	1·88	2·28	2·66	3·10	..	..	..	..
2⅝	1·52	1·98	2·41	2·81	3·19	..	..	..	..
2¾	1·60	2·08	2·54	2·97	3·37	..	..	..	..
2⅞	1·68	2·19	2·67	3·13	3·55	..	..	..	..
3	1·76	2·29	2·80	3·28	3·74	4·17	..	..	..
3⅛	1·84	2·40	2·93	3·44	3·92	4·37	..	..	..
3¼	1·91	2·50	3·06	3·59	4·10	4·58	..	..	..
3⅜	1·99	2·60	3·19	3·75	4·28	4·79	..	..	..
3½	2·07	2·71	3·32	3·91	4·47	5·00	5·51	..	..
3⅝	2·15	2·81	3·45	4·06	4·65	5·21	5·74	..	..
3¾	2·23	2·92	3·58	4·22	4·83	5·42	5·98	..	..
3⅞	2·30	3·02	3·71	4·38	5·01	5·63	6·21	..	..
4	2·38	3·13	3·84	4·53	5·20	5·83	6·45	7·03	..
4⅛	2·46	3·23	3·95	4·69	5·38	6·04	6·68	7·29	..
4¼	2·54	3·33	4·10	4·84	5·56	6·25	6·91	7·55	..
4⅜	2·62	3·44	4·23	5·00	5·74	6·46	7·15	7·81	..
4½	2·70	3·54	4·36	5·16	5·92	6·67	7·38	8·07	8·74

Weight of Angle and Tee Iron in lbs., per Lineal Foot—continued.

Breadths of flanges added (inches).	Thickness in Fraction of an inch.														Breadths of flanges added (inches).
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	
4⅝	2.77	3.65	4.49	5.31	6.11	6.88	7.62	8.33	9.02	..	..	..	..	..	4⅝
4¾	2.85	3.75	4.62	5.47	6.29	7.08	7.85	8.59	9.31	..	..	..	..	..	4¾
4⅞	2.93	3.85	4.75	5.63	6.47	7.29	8.09	8.85	9.6[illegible]	..	..	..	..	..	4⅞
5	3.01	3.96	4.88	5.78	6.65	7.50	8.32	9.11	9.83	10.63	..	..	..	..	5
5⅛	3.09	4.00	5.01	5.94	6.84	7.71	8.55	9.3[illegible]	10.17	10.94	..	..	..	..	5⅛
5¼	3.16	4.17	5.14	6.09	7.02	7.92	8.79	9.6[illegible]	10.46	11.23	..	..	..	..	5¼
5⅜	3.24	4.27	5.27	6.25	7.20	8.13	9.02	9.90	10.74	11.56	..	..	..	..	5⅜
5½	3.32	4.38	5.40	6.41	7.38	8.33	9.26	10.16	11.03	11.88	12.[illegible]0	..	..	..	5½
5⅝	3.40	4.48	5.53	6.56	7.57	8.54	9.49	10.42	11.32	12.19	13.03	..	..	..	5⅝
5¾	3.48	4.58	5.66	6.72	7.75	8.75	9.73	10.68	11.60	12.50	13.37	..	..	..	5¾
5⅞	3.55	4.69	5.79	6.88	7.93	8.96	9.96	10.94	11.89	12.81	13.71	..	..	..	5⅞
6	3.63	4.79	5.92	7.[illegible]3	8.11	9.17	10.20	11.20	12.17	13.13	14.05	14.95	..	..	6
6⅛	3.71	4.90	6.05	7.19	8.29	9.38	10.43	11.46	12.46	13.44	14.39	15.31	..	..	6⅛
6¼	3.79	5.00	6.18	7.34	8.48	9.58	10.66	11.72	12.75	13.75	14.73	15.68	..	..	6¼
6⅜	3.87	5.10	6.32	7.50	8.66	19.79	10.90	11.98	13.03	14.06	15.07	16.04	..	..	6⅜
6½	3.95	5.21	6.45	7.66	8.84	10.00	11.13	12.24	13.[illegible]2	14.38	15.40	16.41	17.38	..	6½
6⅝	4.02	5.31	6.58	7.81	9.02	10.21	11.37	12.50	13.61	14.69	15.74	16.77	17.77	..	6⅝
6¾	4.10	5.42	6.71	7.97	9.21	10.42	11.60	12.76	13.89	15.00	16.08	17.14	18.16	..	6¾
6⅞	4.18	5.52	6.84	8.13	9.39	10.63	11.84	13.02	14.18	15.31	16.42	17.50	18.55	..	6⅞
7	4.26	5.63	6.97	8.28	9.57	10.83	12.07	13.28	14.47	15.63	16.76	17.86	18.95	20.00	7
7⅛	4.34	5.73	7.10	8.44	9.75	11.04	12.80	13.34	14.75	15.94	17.10	18.23	19.34	20.42	7⅛

Weight of Angle and Tee Iron in lb. per Lineal Foot—continued.

Breadths of flanges added (inches).	Thickness in fractions of an inch.														Breadths of flanges added (inches).
	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	
7¼	4·41	5·83	7·23	8·59	9·93	11·25	12·54	13·80	15·04	16·25	17·43	18·59	19·73	20·83	7¼
7⅜	4·49	5·94	7·36	8·75	10·12	11·46	12·77	14·06	15·33	16·56	17·77	18·96	20·12	21·25	7⅜
7½	4·57	6·04	7·49	8·91	10·30	11·67	13·01	14·32	15·61	16·88	18·11	19·32	20·51	21·67	7½
7⅝	4·65	6·15	7·62	9·06	10·48	11·88	13·24	14·58	15·90	17·19	18·45	19·69	20·90	22·08	7⅝
7¾	4·73	6·25	7·75	9·22	10·66	12·08	13·48	14·84	16·18	17·50	18·79	20·05	21·29	22·50	7¾
7⅞	4·80	6·35	7·88	9·38	10·85	12·29	13·71	15·10	16·47	17·81	19·13	20·42	21·68	22·92	7⅞
8	4·88	6·46	8·01	9·53	11·03	12·50	13·95	15·36	17·76	18·13	19·47	20·78	22·07	23·33	8
8⅛	4·96	6·56	8·14	9·69	11·21	12·71	14·18	15·63	17·04	18·44	19·80	21·15	22·46	23·75	8⅛
8¼	5·04	6·67	8·27	9·84	11·39	12·92	14·41	15·89	17·33	18·75	20·14	22·51	22·85	24·17	8¼
8⅜	5·12	6·77	8·40	10·00	11·58	13·13	14·65	16·15	17·62	19·06	20·48	21·87	22·24	24·58	8⅜
8½	5·20	6·88	8·53	10·16	11·76	13·33	14·88	16·41	17·90	19·38	20·82	22·24	23·63	25·00	8½
8⅝	5·27	6·98	8·66	10·31	11·94	13·54	15·12	16·67	18·19	19·69	21·16	22·60	24·02	25·42	8⅝
8¾	5·35	7·08	8·79	10·47	12·12	13·75	15·35	16·93	18·48	20·00	21·50	22·97	24·41	25·83	8¾
8⅞	5·43	7·19	8·92	10·63	12·30	13·96	15·59	17·19	18·76	20·31	21·84	23·33	24·80	26·25	8⅞
9	5·51	7·29	9·05	10·78	12·49	14·17	15·82	17·45	19·05	20·63	22·17	23·70	25·20	26·67	9
9⅛	5·59	7·40	9·81	10·94	12·67	14·38	16·05	17·71	19·34	20·94	22·51	24·06	25·59	27·08	9⅛
9¼	5·66	7·50	9·31	11·09	12·85	14·58	16·29	17·97	19·62	21·25	22·85	24·43	25·98	27·50	9¼
9⅜	5·74	7·60	9·44	11·25	13·03	14·79	16·52	18·23	19·91	21·56	23·19	24·79	26·37	27·92	9⅜
9½	5·82	7·71	9·57	11·41	13·22	15·00	16·76	18·49	20·19	21·88	23·53	25·16	26·76	28·33	9½
9⅝	5·90	7·81	9·70	11·56	13·40	15·21	17·00	18·75	20·48	22·19	23·87	25·52	27·15	28·75	9⅝
9¾	5·98	7·92	9·83	11·72	13·58	15·42	17·23	19·01	20·77	22·50	24·21	25·88	27·54	29·17	9¾

Weight of Angle and Tee Iron in lb., per Lineal Foot—continued.

Breadths of flanges added (inches).	Thickness in fractions of an inch.														Breadths of flanges added (inches).
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	
$9\frac{7}{8}$	6·05	8·02	9·96	11·88	13·76	15·63	17·46	19·27	21·05	22·81	24·54	26·25	27·93	29·58	$9\frac{7}{8}$
10	6·13	8·13	10·09	12·03	13·95	15·83	17·70	19·53	21·34	23·13	24·88	26·61	28·32	30·00	10
$10\frac{1}{8}$	6·21	8·23	10·22	12·19	14·13	16·04	17·93	19·79	21·63	23·44	25·22	26·98	28·71	30·42	$10\frac{1}{8}$
$10\frac{1}{4}$	6·29	8·33	10·35	12·34	14·31	16·25	18·16	20·05	21·91	23·75	25·56	27·34	29·10	30·83	$10\frac{1}{4}$
$10\frac{3}{8}$	6·37	8·44	10·48	12·50	14·49	16·46	18·40	20·31	22·20	24·06	25·90	27·71	29·49	31·25	$10\frac{3}{8}$
$10\frac{1}{2}$	6·45	8·54	10·61	12·66	14·67	16·67	18·63	20·57	22·49	24·38	26·24	28·07	29·88	31·67	$10\frac{1}{2}$
$10\frac{5}{8}$	6·52	8·65	10·74	12·81	14·86	16·88	18·87	20·83	22·77	24·69	26·58	28·44	30·27	32·08	$10\frac{5}{8}$
$10\frac{3}{4}$	6·60	8·75	10·87	12·97	15·04	17·08	19·10	21·09	23·06	25·00	26·91	28·80	30·66	32·50	$10\frac{3}{4}$
$10\frac{7}{8}$	6·68	8·85	11·00	13·13	15·22	17·29	19·34	21·35	23·35	25·31	27·25	29·17	31·05	32·92	$10\frac{7}{8}$
11	6·76	8·96	11·13	13·28	15·40	17·50	19·57	21·61	23·63	25·63	27·59	29·53	31·45	33·33	11
$11\frac{1}{8}$	..	9·06	11·26	13·44	15·59	17·71	19·80	21·88	23·92	25·94	27·93	29·90	31·84	33·75	$11\frac{1}{8}$
$11\frac{1}{4}$	..	9·17	11·39	13·59	15·77	17·92	20·04	22·14	24·21	26·25	28·27	30·26	32·23	34·17	$11\frac{1}{4}$
$11\frac{3}{8}$	..	9·27	11·52	13·75	15·95	18·13	20·27	22·40	24·49	26·56	28·61	30·63	32·62	34·58	$11\frac{3}{8}$
$11\frac{1}{2}$	..	9·38	11·65	13·91	16·13	18·33	20·51	22·66	24·78	28·88	28·95	30·99	33·01	35·00	$11\frac{1}{2}$
$11\frac{5}{8}$	..	..	11·78	14·06	16·32	18·54	20·74	22·92	25·06	27·19	29·28	31·35	33·40	35·42	$11\frac{5}{8}$
$11\frac{3}{4}$	..	..	11·91	14·22	16·50	18·75	20·98	23·18	25·35	27·50	29·62	31·72	33·79	35·83	$11\frac{3}{4}$
$11\frac{7}{8}$	..	..	12·04	14·38	16·68	18·96	21·21	23·44	25·64	27·81	29·96	32·08	34·18	36·25	$11\frac{7}{8}$
12	..	..	12·17	14·53	16·86	19·17	21·45	23·70	25·92	28·13	30·30	32·45	34·57	36·67	12
$12\frac{1}{8}$	..	..	..	14·69	17·04	19·38	21·68	23·96	26·21	28·44	30·64	32·81	34·96	37·08	$12\frac{1}{8}$
$12\frac{1}{4}$	..	..	..	14·84	17·23	19·58	21·91	24·22	26·50	28·75	30·98	33·18	35·35	37·50	$12\frac{1}{4}$
$12\frac{3}{8}$	..	..	..	15·00	17·41	19·79	22·15	24·48	26·78	29·06	31·32	33·54	35·74	37·92	$12\frac{3}{4}$

Weights of Angle and Tee Iron in lbs., per Lineal Foot—concluded.

Breadths of flanges added (inches).	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	Breadths of flanges added (inches).
	Thickness in fractions of an inch.														
12½	..	..	..	15·16	17·59	20·00	22·38	24·74	27·07	29·38	31·65	33·91	36·13	38·33	12½
12⅝	..	..	..	..	17·77	20·21	22·62	25·00	27·36	29·69	31·99	34·27	36·52	38·75	12⅝
12¾	..	..	..	..	17·96	20·42	22·85	25·26	27·64	30·00	32·33	34·64	36·91	39·17	12¾
12⅞	..	..	..	..	18·14	20·63	23·09	25·52	27·93	30·31	32·67	35·00	37·30	39·58	12⅞
13	..	..	..	..	18·32	20·83	23·32	25·78	28·22	30·63	33·01	35·36	37·70	40·00	13
13⅛	..	..	..	..	..	21·04	23·55	26·04	28·50	30·94	33·35	35·73	38·09	40·42	13⅛
13¼	..	..	..	..	..	21·25	23·79	26·30	28·79	31·25	33·68	36·09	38·48	40·83	13¼
13⅜	..	..	..	..	..	21·46	24·02	26·56	29·08	31·56	34·02	36·46	38·87	41·25	13⅝
13½	..	..	..	..	..	21·67	24·26	26·82	29·36	31·88	34·36	36·82	39·26	41·67	13½
13⅝	..	..	..	..	..	21·88	24·49	27·08	29·65	32·19	34·70	37·19	39·65	42·08	13⅝
13¾	..	..	..	..	..	22·08	24·73	27·34	29·93	32·50	35·04	37·55	40·04	42·50	13¾
14⅞	..	..	..	..	..	22·29	24·96	27·60	30·22	32·81	35·38	37·92	40·43	42·92	13⅞
14	..	..	..	..	..	22·50	25·20	27·86	30·51	33·13	35·72	38·28	40·82	43·33	14
14⅛	..	..	..	..	..	22·71	25·43	28·12	30·79	33·44	36·05	38·65	41·21	43·75	14⅛
14¼	..	..	..	..	..	22·92	25·66	28·39	31·08	33·75	36·39	39 01	41·60	44·17	14½
14⅜	..	..	..	..	..	23·13	25·90	28·65	31·37	34·06	36·73	39·38	41·99	44·58	14⅜
14½	..	..	..	..	..	23·33	26·13	28·91	31·65	34·38	37·07	39·74	42·38	45·00	14¼
14⅝	..	..	..	..	..	23·54	26·37	29·17	31·94	34·69	37·41	40·10	42·77	45·42	14½
14¾	..	..	..	..	..	23·75	26·60	29·43	32·23	35·00	37·75	40·47	43·16	45·83	14¾
14⅞	..	..	..	..	..	23·96	26·34	29·69	32·51	35·31	38·09	40·83	43·55	46·25	14⅞
15	..	..	..	..	..	24·17	27·07	29·95	32·80	35·63	38·42	41·20	43·95	46·67	15

Weight of Angle and T-iron.

Add the width of flanges and see the result in the table per foot run.

Example.—To find the weight of T-iron.

Total of flanges$=4+3=7$.

The table gives 6·97 lbs. for $\frac{1}{6}$″.

In case of channel iron divide into two equal parts and see the weight for angle iron of that dimension.

Strength of Angle and T-iron.

If S=Span in feet.

I=Moment of Inertia.

Y=Distance of neutral axis from furthest edge of the section.

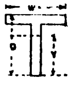
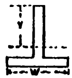
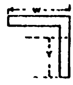
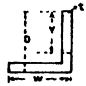
K=Co-efficient for each section.

L=Safe load distributed in lbs. per ft. run including weight of iron.

L=Total load in lbs. distributed over span.

$$L=\frac{K}{S} \qquad I=\frac{K}{5^2}$$

Strength of T and L-iron.

Dimensions of section inches.			Values of Y and I		Values of K for different sections. and positions.			
W Width.	D Depth.	Thickness.	I	Y Inches				
4	4	½	5·5641	2·816	14,750	11,800	11,062	8,850
3	4	½	5·0485	2·6731	14,102	11,282	10,576	8,461
4	3	½	2·4234	2·1731	8,327	6,662	6,245	4,996
3½	3½	½	3·6350	2·4423	11,113	8,890	8,335	6,666
3½	3½	⅜	2·8650	2·4870	8,601	6,882	6,451	5,161
3½	3	½	2·1640	2·0682	7,813	6,250	5,860	4,688
3	3	½	1·7597	2·1125	6,220	4,976	4,665	3,732
2	2¼	½	1·2274	1·6045	5,408	4,326	4,056	3,245
2½	2½	½	·9838	1·7382	4,226	3,381	3,170	2,536
2½	2¼	3/16	·8486	1·7604	3,600	2,881	2,701	2,166
2½	2½	¼	·7031	1·7829	2,945	2,356	2,209	1,767
2	2	½	·5900	1·5214	3,324	2,667	2,500	2,006
2	2½	⅜	·4791	1·3642	2,622	2,098	1,966	1,573
2	2½	5/16	·4163	1·3861	2,242	1,794	1,682	7,345
2	2	¼	;3476	1·4083	1,843	1,474	1,382	1,106
1½	1½	⅜	·1867	0·9911	1,407	1,126	1,055	844
1½	1½	5/16	·1639	1·0124	1,209	967	908	725
1½	1½	¼	·1385	1·0341	1,000	800	750	600
1½	1½	3/16	·1100	1·0563	777	622	583	466
1½	1½	½	·0778	1·0788	538	430	403	326

To find the value of K for those sections not given in the table.

Let I_1 K_1 D_1 be the values of required section

then $I_1 = I \times \frac{D_1{}^4}{D^4}$ and $K_1 = K \times \frac{D_1{}^3}{D^3}$

Example.—Find the value of I_1 and K_1 for a T-iron 4″×4″× 5/16

The table gives I =·41625 } for 2″×2″× 5/16″
and K = 2,242 }

$\therefore I_1 = \frac{4^4}{2^4} \times \cdot 41625 = 6\cdot 66$

and $K_1 = \frac{4^3}{2^3} \times 2242 = 17936.$

Weight of Steel Z-Bars in lb. per foot.

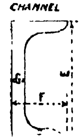
Thickness.	Size. Flange A	Web. W	Flange B	Weight.	Thickness.	Size. Flange A	Web. W	Flange B	Weight.
In.	In.	In.	In.	lbs.	In.	In.	In.	In.	lbs.
7/8	3 5/8	6 1/8	3 5/8	34·6	7/16	3 9/16	6 1/16	3 9/16	18·3
13/16	3 9/16	6 1/16	3 9/16	32·0	7/16	3 3/8	5 1/8	3 3/8	16·4
13/16	3 3/8	5 1/8	3 3/8	28·3	7/16	3 1/16	4	3 1/16	13·8
3/4	3 1/3	6	3 1/2	29·3	7/16	2 3/4	3 1/16	2 3/4	11·4
3/4	3 9/16	5 1/16	3 5/16	26·0	3/8	3 1/2	6	3 1/2	15·6
3/4	3 1/16	4 1/8	3 9/16	22·9	3/8	3	6	3	14·5
11/16	3 3/8	6 1/8	3 5/8	28·0	3/8	3 5/16	5 1/16	3 5/16	13·9
11/16	3 1/4	5	3 1/4	23·7	3/8	3 1/16	4 1/8	3 3/16	12·4
11/16	3 1/2	4 1/16	3 1/8	20·9	3/8	2 1/6	5	3	12·4
5/8	3 9/16	6 1/16	3 9/16	25·4	3/8	2 1/2	4	3	11·1
5/8	3 3/8	5 1/8	3 3/8	22·6	3/8	2 1/2	3	3	10·0
5/8	3 1/16	4	3 1/16	18·9	3/8	2 11/16	3	2 11/16	9·7
9/16	3 1/2	6	3 1/2	22·7	5/16	3 1/4	5	3 1/4	11·6
9/16	3 5/16	5 1/16	3 5/16	20·2	5/16	3 1/8	4 1/16	3 1/8	10·3
9/16	3 3/16	4 1/8	3 3/16	17·9	5/16	2 3/4	3 1/16	2 3/4	8·4
9/16	2 3/4	3 1/16	2 3/4	14·2	5/16	2 1/2	3	3	8·4
1/2	3 5/8	6 1/8	3 5/8	21·0	1/4	3 1/16	4	3 1/16	8·2
1/2	3 1/4	5	3 1/4	17·8	1/4	2 11/16	3	2 11/16	6·7
1/2	3 1/8	4 1/16	3 1/8	15·8	1/8	1 9/16	1 1/8	1 3/8	1·3
1/2	2 11/16	3	2 11/16	12·5	..	1 1/4 × 5/16	1 3/4 × 5/16	2 3/4 × 1/4	4·5

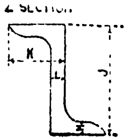
Weight of Coal.

Specific Gravity.	Weight of coal in the natural bed per inch thick per acre.	Weight of a c. ft. of loose coal. Large coal.	Small coal.
	Ton.	lb.	lb.
1·10	111·25	43	38
1·15	116·53	45	39
1·20	121·76	47	41
1·25	126·84	49	43
1·30	131·92	51	43
1·35	136·59	53	44
1·40	141·95	55	46
1·45	146·76	57	48
1·50	152·00	59	49
			51

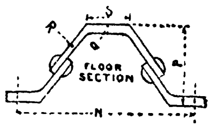
Rolled Steel Channel, Z, and Floor Sections (Dorman, Long & Co.).

Channel, Dimensions in ins. E	F	G	H	lbs. per foot run.	Safe load tons distributed on spans of 5 ft.	10 ft.	15 ft.	20 ft.
4	3	1/2	9/16	16·36	5·88	2·94	..	..
5 1/8	2 7/8	7/16	1/2	15·86	7·48	3·74	..	..
6	3	3/8	7/16	15·69	8·73	4·36	..	..
7	3	1/2	1/2	20·4	12·40	6·20	4·13	..
8	3 1/2	1/2	1/2	23·79	16·94	8·47	5·64	..
10	3	7/16	7/16	22·49	18·72	9·36	6·24	4·68
12	3 1/2	1/2	1/2	30·6	30·44	15·22	10·14	7·61
Z Section.								
J	K	L	M					
4	3	3/8	3/8	11·78	4·52	2·26	..	..
5	3	3/8	3/8	13·05	6·18	3·09	..	..
6	3 1/2	3/8	3/8	15·61	9·00	4·50	3·0	..
8	3 1/2	3/8	3/8	18·15	13·36	6·68	4·45	..





Floor-Section Dimensions, inches. N	P	Q	R	S	Per Sq. Ft. Wgt. lbs.	Safe Load cwts.
12	4	1/4	1/8	4	13·4	4·2*
12	4 1/4	3/8	3/16	4	19·0	5·6
14	5	5/16	3/16	4 1/2	17·6	6·2
14	5 1/4	7/16	1/4	4 1/2	23·1	8·2
10	6	3/8	1/4	5 1/8	21·8	8·7
16	6 1/4	1/2	5/16	5 1/8	28·0	11·3
20	7	7/16	9/32	6	24·5	11·2
20	7 3/8	5/8	3/8	6	33·0	15·9
24	9	7/16	9/32	7 1/2	26·2	15·8
24	9 3/8	5/8	3/8	7 1/2	35·0	22·3
32	12 1/2	3/4	1/2	9	40·5	33·6
32	13	1	5/8	9	51·8	44·1



*Note.—The safe load is in cwts per square foot for spans of 10 feet. For other spans divide the tabular number by one-tenth of the span squared.

Dimensions and Properties of I Beams (in inch units).

Size Inches.	Weight per Foot lbs.	Web.	Flange.	Area Square Inches.	Moments of Inertia About X-X	Moments of Inertia About Y-Y	Radii of Gyration Inches About X-X	Radii of Gyration Inches About Y-Y	Section Modulus About X-X
24×7½	100	·6	1·07	29·4	2654	66·92	9·5	1·5	221·1
20×7½	89	·6	1·01	26·17	1670	62·63	7·99	1·54	167·0
20×6¼	65	·493	·79	19·12	1178	27·40	7·85	1·20	117·8
18×7	75	·55	·928	22·06	1149	47·04	7·21	1·46	127·6
18×6	55	·466	·691	16·18	806·3	20·84	7·06	1·13	89·59
16×6	62	·55	·847	18·25	725·7	27·08	6·31	1·21	90·71
15×6	59	·5	·88	17·35	628·9	28·22	6·02	1·27	83·85
15×5	42	·42	·647	12·35	428·	11·81	5·88	·978	57·06
14×6	57	·5	·873	16·76	532·9	27·96	5·63	1·29	76·12
14×6	46	·4	·698	13·53	440·5	21·6	5·7	1·26	62·92
12×6	54	·5	·883	15·88	375·5	28·3	4·86	1·33	62·58
12×6	44	·4	·717	12·94	315·3	22·27	4·93	1·31	52·55
12×5	39	·44	·664	11·47	260·9	12·16	4·77	1·03	43·48
12×5	32	·35	·55	9·41	220·	9·753	4·83	1·01	36·66
10×8	70	·6	·97	20·6	344·9	71·67	4·09	1·86	68·98
10×6	42	·4	·736	12·35	211·5	22·95	4·13	1·36	42·3
10×5	35	·42	·652	10·29	167·2	11·89	4·03	1·07	33·45
10×5	30	·36	·552	8·82	145·6	9·79	4·06	1·05	29·12
10×4·66	25	·3	·491	7·353	122·7	6·778	4·08	·960	24·53
9×7	58	·55	·924	17·06	229·5	46·3	3·66	1·64	51·0
9¼×3¾	23·5	·34	·453	6·324	83·41	3·446	3·63	·738	18·03
9×4	21	·3	·46	6·176	81·1	4·2	3·62	·824	18·02
8×6	35	·44	·597	10·29	110·5	17·95	3·27	1·32	27·62
8×5	28	·35	·575	8·24	89·32	10·26	3·29	1·11	22·33
8×4	18	·28	·402	5·294	55·69	3·578	3·24	·822	13·92
7×4	16	·25	·387	4·706	39·21	3·414	2·88	8·51	11·2
6×5	25	·41	·52	7·35	43·61	9·116	2·43	1·11	14·53
6×4½	20	·37	·431	5·88	34·62	5·415	2·42	·959	11·54
6×3	12	·26	·348	3·53	20·21	1·339	2·39	·616	6·736
5×4½	18	·29	·448	5·29	22·69	5·664	2·07	1·03	9·076
5×3	11	·22	·376	3·235	13·61	1·462	2·05	·672	5·444
4¾×1¾	6·5	·18	·325	1·912	6·73	·263	1·87	·37	2·833
4×3	9·5	·22	·336	2·794	7·52	1·281	1·64	·677	3·76
4×1¾	5	·17	·24	1·47	3·668	·186	1·58	·355	1·834
3×3	8·5	·2	·332	2·5	3·787	1·262	1·23	·71	2·524
3×1½	4	·16	·248	1·176	1·659	·124	1·18	·324	1·106

Dorman, Long & Co.

Table of Manilla Rope of good quality.

Circumference. Inches.	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
Weight per yard. lbs.	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	1	$1\frac{1}{8}$
Breaking strain Tons	0·35	0·56	0·80	1·10	1·4	1·8	2·4	2·8	3·2	3·9	4·4

Circumference. Ins.	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8
Weight per yard, lbs	$1\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{11}{16}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{13}{16}$	$4\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{13}{16}$
Breaking strain. Tons	5·2	5·8	6·6	7·4	8·0	9·0	11·0	13·0	15·2	17·8	20·4	23·2

Note.—The safe working load for Ropes is one-eighth of the breaking strain.

Table of Manilla Ropes.

Diam.	Circ.	Weight per ft.	Breal		Diam.	Circ.	Weight per ft.	Breaking load.	
Ins.	Ins.	lb.	tons.	lbs.	Ins.	Ins.	lb.	tons.	lb.
·239	$\frac{3}{4}$	·019	·25	560	1·91	6	1·19	11·4	25536
·318	1	·033	·35	784	2·07	$6\frac{1}{2}$	1·39	13·0	29120
·477	$1\frac{1}{2}$	·074	·70	1568	2·23	7	1·63	14·6	327 4
·636	2	·132	1·21	2733	2·39	$7\frac{1}{2}$	1·86	16·2	36288
·795	$2\frac{1}{2}$	·206	1·91	4278	2·55	8	2·11	17·8	39872
·955	3	.297	2·73	6115	2·86	9	2·67	21·0	47040
1·11	$3\frac{1}{2}$	·404	3·81	8534	3·18	10	3·30	24·2	54208
1·27	4	·528	5·16	11558	3·50	11	3·99	27·4	61376
1·43	$4\frac{1}{2}$	·668	6·60	14784	3·82	12	4·75	30·6	68544
1·59	5	·825	8·20	18368	4·14	13	5·58	33·8	75712
1·75	$5\frac{1}{2}$	·998	9·80	21952	4·45	14	6·47	37·0	82880

The above table gives values for an average manilla ropes. Good Italian hemp ropes are better than manilla ropes but they are costly.

Tar coal application to ropes makes them weak.

Horse-power of Manilla Ropes.

Diam. Inches.	Speed of Rope in feet per minute.								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
	Horse-power.								
¾	1¾	2¾	3½	4½	5½	6½	7	8¼	9
1	3½	4⅞	6½	8	10	11	13	15	16
1¼	5⅛	7½	10¼	13	15	18	20	23	26
1½	7½	11	15	18	22	26	30	34	37
1¾	10	15	20	25	30	35	40	45	50
2	13	1⁹½	26	33	39	46	52	59	65

Approx. weight of ropes per yard $= D^2$ lbs. where

D = diameter of ropes in inches.

Table of Weights of Ropes in lbs. per lineal yard.

Circum. Inches.	Hemp.		Wire.		Circum. Inches.	Hemp.	
	Common	Good.	Iron.	Steel.		Common.	Good.
1	·09	·12	·43	·44	4¼	1·62	2·17
1¼	·14	·19	·68	·70	4½	1·83	2·43
1½	·21	·27	·98	1·00	4¾	2·03	2·71
1¾	·28	·37	1·33	1·36	5	2·25	3·00
2	·36	·48	1·74	1·78	5½	2·72	3·63
2¼	·45	·61	2·20	2·25	6	3·24	4·32
2½	·57	·75	2·72	2·78	6½	3·81	5·07
2¾	·68	·91	3·29	3·36	7	4·41	5·88
3	·81	1·08	3·92	4·01	7½	5·06	6·75
3¼	·96	1·27	4·59	4·70	8	5·76	7·68
3½	1·10	1·47	5·33	5·45	8½	6·53	8·67
3¾	1·27	1·69	6·12	6·26	9	7·29	9·72
4	1·44	1·92	6·96	7·12	10	9·00	12·00

Hemp and Iron Wire Ropes.

Rule for finding the weight and strength of hemp ropes.

Let C = circumference of rope in inches.

W = weight of rope in lbs. for 1 yard.

then $W = C^2 \times \frac{1}{8}$

S = Breaking weight in maunds $= C^2 \times \frac{2}{3}$

Table of Working Strength of Ropes in Tons.

Circum. Inches.	Hemp.		Wire.		Circum. Inches.	Hemp.	
	Common.	Good.	Iron.	Steel.		Common.	Good.
1	·032	·046	·29	·45	4¼	·578	·831
1¼	·050	·072	·45	·70	4½	·648	·932
1½	·072	·104	·65	1·01	4¾	·722	1·038
1¾	·098	·141	·89	1·38	5	·800	1·150
2	·128	·148	1·16	1·80	5½	·968	1·392
2¼	·162	·233	1·47	2·28	6	1·152	1·656
2½	·200	·288	1·81	2·81	6½	1·352	1·944
2¾	·242	·348	2·19	3·40	7	1·568	2·254
3	·288	·414	2·61	4·05	7½	1·800	2·588
3¼	·338	·486	3·06	4·75	8	2·048	2·944
3½	·392	·564	3·55	5·51	8½	2·312	3·324
3¾	·450	·647	4·08	6·33	9	2·592	3·726
4	·512	·736	4·64	7·20	10	8·200	4·600

Weight and Strength of Wire Ropes.

Rope of 133 *Wires* (19 *wires in a Strand*).

Trade No.	Diam. inches.	Circum. inches.	Pounds per foot.	Breaking load, lbs.	
				Iron.	Cast steel.
1	2¼	6¾	8·00	1,48,000	2,60,000
2	2	6	6·30	1,30,000	2,00,000
3	1¾	5½	5·25	1,08,000	1,56,000
4	1⅝	5	4·10	88,000	1,28,000
5	1½	4¾	3·65	78,000	1,10,000
5½	1⅜	4⅜	3·00	66,000	..
6	1¼	4	2·50	54,000	78,000
7	1⅛	3½	2·00	40,000	60,000
8	1	3⅛	1·58	32,000	48,000
9	⅞	2¾	1·20	23,000	40,000
10	¾	2¼	0·88	17,280	26,000
10¼	⅝	2	0·70	10,260	18,000
10½	$\frac{9}{16}$	1⅝	0·44	8,540	13,000
10¾	½	1½	0·35	6,960	11,000
10⅞	⅜	1¼	0·26	5,000	..

Breaking strain of steel wire ropes $= C^2 \times 6$ maunds.

$W = \text{Weight} = C \times \frac{7}{16}$

Weight and Strength of Wire Ropes—concld.

Rope of 49 *Wires* (7 *Wires to a Strand*).

Trade No.	Diam. inches.	Circum. inches.	Pounds per foot.	Breaking loads, lbs.	
				Iron.	Cast steel.
11	$1\frac{1}{2}$	$4\frac{5}{8}$	3·37	72,000	1,34,000
12	$1\frac{3}{8}$	$4\frac{1}{4}$	2·77	60,000	1,10,000
13	$1\frac{1}{4}$	$3\frac{3}{4}$	2·28	50,000	90,000
14	$1\frac{1}{8}$	$3\frac{3}{8}$	1·82	40,000	72,000
15	1	3	1·50	32,000	60,000
16	$\frac{7}{8}$	$2\frac{5}{8}$	1·12	24,600	44,000
17	$\frac{3}{4}$	$2\frac{3}{8}$	0·88	17,600	34,000
18	$\frac{11}{16}$	$2\frac{1}{8}$	0·70	15,200	27,000
19	$\frac{5}{8}$	$1\frac{7}{8}$	0·57	11,600	20,000
20	$\frac{9}{16}$	$1\frac{5}{8}$	0·41	8,200	16,000
21	$\frac{1}{2}$	$1\frac{3}{8}$	0·31	5,660	12,000
22	$\frac{7}{16}$	$1\frac{1}{4}$	0·23	4,260	..
23	$\frac{3}{8}$	$1\frac{1}{8}$	0·19	3,300	8,000
24	$\frac{5}{16}$	1	0·16	2,760	6,000
25	$\frac{9}{32}$	$\frac{7}{8}$	0·125	2,060	..

Safe strength $=\frac{1}{5}$ to $\frac{1}{7}$ of breaking strength

Let C = Circumference in inches,

the Breaking Strength in tons :—

for ropes used in ships $= \cdot 20C^2$

Twisted ropes $= \cdot 28C^2$

Wire ropes $= 1 \cdot 4C^2$

Steel wire rope $= 2 \cdot 5C^2$

Example.—Find the circumference of a wire to carry a stress of 10 tons with factor of safety of 6

Breaking strength $= 10 \times 6 = 60$ tons $= 1 \cdot 4\ C^2$

$\therefore C = 6 \cdot 5$ inches.

Weight and Strength of Hemp and Wire Rope.

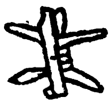
Circumference.	Iron wire rope.		Steel wire rope.		Hemp rope. (Hawser).		Hemp rope. (Shroud).		Hemp rope. (Cable).	
	Test load.	Weight per yard.	Test load.	Weight per yard.	Test load.	Weight per yard.	Test load.	Weight per yard.	Test load.	Weight per yard.
Ins.	Ton.	lbs.	Ton.	lbs.	Ton.	lbs.	Ton.	lbs.	Ton.	lbs.
½	·30	·17	·45	·18	..	..	..	..	..	..
¾	·45	·28	·68	·28	..	..	..	..	..	..
1	·75	·49	1·13	·51	·25	·13	·20	·12	..	..
1¼	1·00	·75	1·50	·78	..	..	..	..	..	..
1½	1·55	1·03	2·33	1·06	·55	·25	·44	·25	..	..
1¾	2·30	1·50	3·45	1·54	..	..	..	..	..	..
2	3·00	1·94	4·50	1·75	1·100	·5	·80	·49	·64	·32
2¼	4·00	2·37	6·00	2·44	..	..	..	..	..	..
2½	4·50	2·87	6·75	2·94	1·55	·75	1·24	·73	·99	·48
2¾	5·50	3·5	8·25	3·60	..	..	..	..	..	..
3	7·10	4·25	10·65	4·37	2·25	1·0	1·80	·97	1·44	·64
3¼	8·00	4·5	12·00	4·63	..	..	..	..	..	..
3½	9·35	5·4	14·02	5·56	3·05	1·50	2·44	1·46	1·95	·96
3¾	10·0	5·75	15·00	5·92	..	..	..	..	..	..
4	11·8	6·65	17·70	6·8	4·00	1·87	3·20	1·82	2·56	1·20
4½	15·8	8·9	23·70	9·16	4·50	2·34	4·40	2·30	2·88	1·52
5	18·6	10·75	27·90	11·07	6·25	3·0	5·00	2·91	4·00	1·92
5½	22·5	13·25	33·75	13·64	7·55	3·62	6·04	3·51	4·83	2·32
6	27·2	15·75	40·80	16·22	9·00	4·25	7·20	4·10	5·76	2·72
6½	32·1	18·4	48·15	18·95	10·55	5·0	8·44	4·85	6·76	3·20
7	36·3	21·25	54·45	21·89	12·25	5·75	9·80	5·58	7·84	3·68
7½	41·3	23·4	61·95	24·10	13·80	6·62	11·04	6·42	8·83	4·24
8	..	..	..	..	16·00	7·5	12·80	7·28	10·24	4·80
8½	..	..	..	..	18·05	8·5	14·44	8·25	11·55	5·44
9	..	..	..	..	20·25	9·5	16·20	9·25	12·96	6·08
9½	..	..	..	..	22·55	10·62	18·04	10·30	14·43	6·80
10	..	..	..	..	25·00	11·75	20·00	11·40	16·00	7·52
10½	..	..	..	..	27·50	12·87	22·00	12·48	16·60	8·24
11	..	..	..	..	30·25	14·25	24·20	13·82	19·36	9·12
12	..	..	..	..	36·00	17·00	28·80	16·45	23·04	10·88
13	..	..	..	..	..	..	..	..	27·04	12·72

Galvanized Flexible Steel Wire Rope.

6 Strands of 12 wire each construction.

Size.		Approximate breaking strain in lbs.	Weight per fathom in lbs.	Weight per 100 R. ft. in lbs.
Circum. in inch.	Diam. inches.			
½	$\frac{5}{32}$	½	..	3¼
¾	¼	1⅛	..	8½
⅞	$\frac{9}{32}$	1½	..	..
1	$\frac{5}{16}$	1¾	·70	12½
1¼	⅜	2⅞	1·08	22½
1½	$\frac{15}{32}$	4	1·39	30
1¾	$\frac{9}{16}$	5½	1·77	35
2	⅝	7	2·47	46
2¼	$\frac{23}{32}$	9½	2·96	53
2½	$\frac{13}{16}$	12½	3·86	63
2¾	⅞	15½	4·66	89
3	$\frac{15}{16}$	18	5·49	98
3¼	$1\frac{1}{32}$	22	6·50	126
3½	1⅛	26	7·50	140
3¾	$1\frac{3}{16}$	29	8·61	162
4	1¼	33	9·80	170
4¼	$1\frac{11}{32}$	35	11·10	196
4½	$1\frac{7}{16}$	39	12·45	224
4¾	..	..	..	259
5	..	..	..	308
5½	..	..	..	343
6	..	..	..	510

Galvanized Steel Barb Fencing Wire.

Style.	Description.	Weight of		Length of 112 lbs.
		100 yds.	Mile.	
	2 point ordinary barb round one wire 5″ apart.	lbs. 19	lbs. 335	589 yds.
	2 point thickest barb round one wire only 2½″ apart.	21	370	533 yds.
	4 point ordinary barb round one wire only 6″ apart.	20	352	560 yds.
	4 point thickest barb round one wire only 3″ apart.	25	440	448 yds.
	4 point ordinary barb round both wires 6″ apart.	20	358	560 yds.
	4 point thickest barb round both wires 3″ apart.	25	440	448 yds.

GALVANIZED FENCING STRAND.

Three ply.

Gauge.	Size of Single Wire.	Weight per Mile, Lbs.	Length per Cwt., Yards.
0	8	1100	179
1	8½	994	198
2	9	800	246
3	10	704	280
4	11	580	340
5	12	466	423
6	12½	414	476
7	13¼	340	580
8	14	275	717
9	15	223	884
10	16	176	1120

Five ply.

Gauge.	Size of Single Wire.	Weight per Mile, Lbs.	Length per Cwt. Yards.
0	10½	1070	184
1	11½	870	226
2	12	778	253
3	13	607	324
4	13½	530	372
5	14	460	428
6	15	372	530
7	16	294	670
8	16½	250	788
9	17	225	876
10	18	165	1194

Four ply.

Gauge.	Size of Single Wire.	Weight per Mile, Lbs.	Length per Cwt., Yards.
0	9½	1063	185
1	10½	855	231
2	11	773	255
3	12	620	318
4	12½	552	356
5	13¼	454	434
6	14	367	537
7	14½	330	593
8	15½	265	743
9	16¼	220	896
10	17	180	1095

Seven ply.

Gauge.	Size of Single Wire.	Weight per Mile, Lbs.	Length per Cwt. Yards.
½	7½	2840	69
7/16	9	2085	95
⅜	11½	1211	162
5/16	12	1085	182
1	12½	963	205
2	13	850	232
3	13½	741	266
4	14¼	610	323
5	15	520	379
6	16	410	481
7	16½	351	560
8	17¼	292	675
9	18	230	853
10	18½	195	1011

Weight and Strength of Flat Ropes of Hemp and Wire.

Hemp.		Iron Wire.		Steel Wire.		Equivalent strength.	
Size.	Weight per fathom.	Size.	Weight per fathom.	Size.	Weight per fathom.	Working load per cwt.	Breaking strain per ton.
Inches.	lbs.	Inches.	lbs.	Inches.	lbs.		
4 × 1⅛	20	2¼ × ½	11	..	..	44	20
5 × 1¼	24	2½ × ½	13	..	..	52	23
5½ × 1⅜	26	2¾ × ⅝	15	..	..	60	27
5¾ × 1½	28	3 × ⅝	16	2 × ½	10	64	28
6 × 1½	30	3¼ × ⅝	18	2¼ × ½	11	72	32
7 × 1⅞	36	3½ × ⅝	20	..	..	80	36
8¼ × 2⅛	40	3¾ × 11/16	22	2½ × ½	13	88	40
8½ × 2¼	45	4 × 11/16	25	2¾ × ⅜	15	100	45
9 × 2½	50	4¼ × ¾	28	3 × ⅜	16	112	50
9½ × 2⅝	55	4½ × ¾	32	3¼ × ⅜	18	128	56
10 × 2½	60	4⅜ × ¾	34	3½ × ⅜	20	136	60

Weight and Strength of Iron Chains.

Diameter of iron in links.	Weight of chain per ft.	Breaking strain of the chain.		Diam. of iron in links.	Weight of chain per ft.	Breaking strain of the chain.	
Ins.	lbs.	lbs.	Tons.	Ins.	lbs.	lbs.	Tons.
3/16	·5	1,731	·773	1	10·7	49,280	22·00
¼	·8	3,069	1·37	1⅛	12·0	59,226	26·44
5/16	1·0	4,794	2·14	1¼	16·	73,114	32·64
⅜	1·7	6,922	3·09	1⅜	18·3	88,301	39·42
7/16	2	9,408	4·20	1½	21·7	1,05,280	47·00
½	2·5	12,320	5·50	1⅝	26	1,23,514	55·14
9/16	3·2	15,590	6·96	1¾	28	1,43,293	63·97
⅝	4·3	19,219	8·58	1⅞	32	1,64,505	73·44
11/16	5	23,274	10·39	2	38	1,87,152	83·55
¾	5·8	27,687	12·36	2¼	54	2,24,448	100·2
13/16	6·7	32,501	14·42	2½	71	2,77,088	123·7
⅞	8	37,632	16·80	2¾	88	3,35,328	149·7
15/16	9	43,277	19·32	3	105	3,98,944	178·1

Rule for finding the breaking weight of iron chains.

To find the breaking weight in tons divide the square of the diameter of one bar of the link in sixteenth of an inch by 10.

Example.—To find the breaking weight in tons of a chain, the diameter of whose link is $\frac{1}{4}$ inch.

$$\text{Diam.} = \tfrac{1}{4} = \tfrac{4}{16} = \therefore \text{ weight } = \frac{4 \times 4}{10} = 1{\cdot}6 \text{ tons.}$$

The safe working load should not be more than $\frac{1}{6}$th the breaking weight.

Strength and weight of short link tested crane chains.

Diam. of Iron in Link.	Breaking weight.	Proof Load.	Safe working Load.	Weight per fathom.	Diam. of Iron in Link.	Breaking weight.	Proof Load.	Safe working Load.	Weight per fathom.
Ins.	Tons.	Tons.	Tons.	lbs.	Ins.	Tons.	Tons.	Tons.	lbs.
$\frac{3}{16}$	·84	·42	·25	2·1	$\frac{7}{8}$	18·25	9·12	5·44	46·50
$\frac{1}{4}$	1·5	·75	·44	4·88	$\frac{15}{16}$	21·00	10·50	6·25	58·00
$\frac{5}{16}$	2·25	1·13	·67	7·26	1	24·00	12·00	7·11	63·50
$\frac{3}{8}$	3·25	1·62	1·00	10·57	$1\frac{1}{8}$	30·50	15·25	9·00	78·50
$\frac{7}{16}$	4·50	2·25	1·36	13·00	$1\frac{1}{4}$	37·50	18·75	11·11	93·00
$\frac{1}{2}$	6·00	3·00	1·77	16·00	$1\frac{3}{8}$	45·25	22·62	13·24	121·00
$\frac{9}{16}$	7·50	3·75	2·25	21·00	$1\frac{1}{2}$	54·00	27·00	16·00	144·00
$\frac{5}{8}$	9·25	4·62	2·78	25·00	$1\frac{5}{8}$	63·25	31·62	18·77	169·00
$\frac{11}{16}$	11·25	5·62	3·36	29·00	$1\frac{3}{4}$	73·50	36·75	21·77	196·00
$\frac{3}{4}$	13·50	6·75	4·00	36·00	$1\frac{7}{8}$	85·00	42·50	25·00	225·00
$\frac{13}{16}$	15·75	7·87	4·70	43·00	2	96·00	48·00	28·44	256·04

Weight and strength of chain.

Stud chain.						Rigging chain.					
Diameter.	Test Load.	Wt. per Fath.	Diameter.	Test Load.	Wt. per Fath.	Diameter.	Test Load.	Wt. per Fath.	Diameter.	Test Load.	Wt. per Fath.
Ins.	Tons.	lbs.	Ins.	Tons.	lbs.	Ins.	Tons.	lbs.	Ins.	Tons.	lbs.
$\frac{5}{8}$	7·0	24	$1\frac{5}{8}$	47·5	145	$\frac{1}{8}$	·12	·48	$\frac{13}{16}$	7 92	42
$\frac{11}{16}$	8·5	28	$1\frac{3}{4}$	58·1	170	$\frac{3}{16}$	·41	1·64	$\frac{7}{8}$	9·19	50
$\frac{3}{4}$	10·1	32	$1\frac{7}{8}$	63·3	195	$\frac{1}{4}$	·75	4·5	$\frac{15}{16}$	10·55	57
$\frac{13}{16}$	11·5	37	2	72·0	230	$\frac{5}{16}$	1·17	6·0	1	12·00	65
$\frac{7}{8}$	13·8	44	$2\frac{1}{8}$	81·3	236	$\frac{3}{8}$	1·69	10·5	$1\frac{1}{16}$	13·54	73
$\frac{15}{16}$	15·0	49	$2\frac{1}{4}$	91·1	285	$\frac{7}{16}$	2·30	12·0	$1\frac{1}{8}$	15·18	82
1	18·0	58	$2\frac{3}{8}$	101·5	320	$\frac{1}{2}$	3·00	18·0	$1\frac{3}{16}$	16·92	91
$1\frac{1}{8}$	22·8	72	$2\frac{1}{2}$	112·5	360	$\frac{9}{16}$	3·80	21·0	$1\frac{1}{4}$	18·75	101
$1\frac{1}{4}$	28·1	90	$2\frac{5}{8}$	120·6	398	$\frac{5}{8}$	4·69	27·9	$1\frac{3}{16}$	20·67	110
$1\frac{3}{8}$	34·0	110	$2\frac{3}{4}$	129·3	438	$\frac{11}{16}$	5·67	31·3	$1\frac{3}{8}$	22·68	120
$1\frac{1}{2}$	40·5	125	$2\frac{7}{8}$	137·0	479	$\frac{3}{4}$	6·75	36·0	$1\frac{1}{2}$	27·0	140

Table of working load of iron chains in maunds.

Diam.	Ins.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Load.	Mds.	12·3	19·6	28·	38·	49·8	63·	77·8	94·	112
Diam.	Ins.	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$
Load.	Mds.	131·3	152·	178·	199·	252·	311·	376·	448·	610·

Table of Chain, Hemp and Iron Wire Ropes considered to be of equal strength.

Chain. Diam. of Iron in link, ins.	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
Hemp Rope Circum. ins.	3	4	5	6	7	8	9	10
Wire Circum. ins.	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	

Proportions, weight and strength of ordinary chains.

Diam. of chain.	Outside length.	Outside width	Diagonal width.	Safe load.		Breaking load.		Weight per fathom.
Ins.	Ins.	Ins.	Ins.	Tons.	Cwts.	Tons.	Cwts.	lbs.
1/4	1	7/8	11/16	..	12 1/2	1	5 1/2	3 1/2
5/16	1 1/4	1 1/16	27/32	..	12 1/2	1	5 1/2	5 1/2
3/8	1 1/2	1 1/4	1	..	18	1	17	8
7/16	1 3/4	1 7/16	1 5/32	1	4 1/2	2	10	10 1/2
1/2	2 3/8	1 11/16	1 3/8	1	12	3	5	14
9/16	2 11/16	1 7/8	1 1/2	2	1	4	3	18
5/8	2 7/8	2 1/16	1 21/30	2	10	5	2	22
11/16	3 1/4	2 1/4	1 13/16	3	1	6	4	27
3/4	3 5/8	2 1/2	2	3	12	7	7	32
13/16	3 3/4	2 5/8	2 1/8	4	5	8	13	37
7/8	4 1/8	2 13/16	2 1/8	4	18	10	..	43
15/16	4 3/8	3 1/8	2 1/2	5	13	11	11	49
1	4 1/2	3 1/4	2 5/8	6	4	13	8	56
1 1/16	4 11/16	3 1/2	2 13/16	7	6	14	8	63
1 1/8	5 3/16	3 11/16	2 15/16	8	4	16	14	71
1 3/16	5 11/16	3 7/8	3 16/30	9	2	18	11	79
1 1/4	5 7/8	4	3 3/16	10	..	20	8	87
1 5/16	6 1/4	4 1/4	3 5/8	11	2	22	13	96
1 3/8	6 7/8	4 1/2	3 3/8	12	4	24	18	106
1 1/2	7 1/4	4 7/8	3 7/8	13	8	29	8	126

Weight of Leather Belting.

Breadth, Ins...	1 3/4	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2
Single, lbs. ..	·20	·23	·29	·35	·40	·46	·52	·58	·63
Double, lbs. ..	·40	·46	·58	·70	·80	·92	1·04	1·16	1·26

Breadth, Ins...	6	6 1/2	7	7 1/2	8	9	10	11	12
Single, lbs. ..	·69	·75	·81	·86	·92	1·04	1·15	1·27	1·38
Double, lbs. ..	1·38	1·60	1·62	1·72	1·84	2·08	2·30	2·54	2·76

IMPERIAL STANDARD WIRE GAUGE.

Table of sizes, weights, lengths, and breaking strains of steel wire.

Diameter Inches.	Size on Wire Gauge.	DIAM.	Sectional area in square inches.	APPROXIMATE WEIGHT OF			APPROXIMATE LENGTH OF		APPROXIMATE BREAKING SPRAINS.	
		Dec. of an inch.		100 Yards.	Mile.	Kilo-metre.	Cwt.	100 Kilos.	25 Tons per sq. in.	35 Tons per sq. in.
				lbs.	lbs.	lbs.	yds.	yds.	lbs.	lbs.
1/2	7/0	·500	·19635	200·11	3522	2188	56	110	10995	15393
15/32	6/0	·464	·16910	172·33	3033	1885	65	128	9469	13257
7/16	5/0	·432	·14657	149·37	2629	1634	75	147	8208	11490
13/32	4/0	·400	·12568	128·07	2254	1400	87·5	172	7035	9851
3/8	3/0	·372	·10869	110·8	1950	1211	101	198	6086	8521
11/32	2/0	·348	·09510	96·93	1706	1060	115	226	5326	7457
..	1/0	·324	·08244	84·03	1479	919	133	261	4616	6463
..	1	·300	·07069	72·04	1268	788	155	305	3958	5542
..	2	·276	·05982	60·97	1073	667	183	360	3350	4690
1/4	3	·252	·04987	50·85	895	556	220	433	2792	3910
..	4	·232	·04227	43·07	758	471	260	512	2366	3313
..	5	·212	·03530	35·97	633	393	311	612	1977	2767
3/16	6	·192	·02896	29·43	518	323	380	748	1621	2269
..	7	·176	·02432	24·77	436	271	452	890	1362	1908
..	8	·160	·02011	20·45	360	224	546	1075	1125	1576
..	9	·144	·01628	16·59	292	182	675	1329	911	1276
1/8	10	·128	·01287	13·12	231	143	854	1681	720	1008
..	11	·116	·01057	10·80	190	118	1040	2047	592	828
..	12	·104	·00850	8·63	152	95	1293	2545	475	666
3/32	13	·092	·00665	6·76	119	74	1653	3254	373	521
..	14	·080	·00503	5·11	90	56	2186	4303	281	394
..	15	·072	·00407	4·15	73	45	2699	5313	227	318
1/16	16	·064	·00322	3·29	58	36	3416	6724	180	252
..	17	·056	·00246	2·50	44	27·5	4462	8783	138	192
3/64	18	·048	·00181	1·83	32·5	20·2	6073	11954	101	141
..	19	·040	·00126	1·27	22·54	14·0	8745	17214	70	98
..	20	·036	·00102	1·03	18·25	11·34	10796	21251	57	79
1/32	22	·028	·00062	·628	11·04	6·86	17846	35128	34·4	48·2
3/128	24	·022	·00038	·387	6·82	4·24	28908	56903	21·2	29·8
..	26	·018	·00025	·259	4·56	2·84	43184	85003	14·2	19·9
1/64	28	·0148	·00017	·175	3·09	1·92	63877	125735	9·6	13·5
..	30	·0124	·00012	·123	2·17	1·35	90996	179118	6·8	9·5

Sectional Areas of Rivet Holes in Plates of Various Thicknesses, Taken ⅛ inch in Excess of Diameter of Rivet.

Thickness of plate.	1 inch Rivets.								⅞ inch Rivets.								Thickness of plate.
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
1	1·12	2·25	3·37	4·50	5·62	6·75	7·87	9·00	1·00	2·00	3·00	4·00	5·00	6·00	7·00	8·00	1
$\frac{15}{16}$	1·05	2·10	3·16	4·21	5·27	6·32	7·38	8·43	·94	1·87	2·81	3·75	4·68	5·62	6·56	7·50	$\frac{15}{16}$
$\frac{7}{8}$	·98	1·97	2·95	3·93	4·92	5·90	6·89	7·87	·87	1·75	2·62	3·50	4·37	5·25	6·12	7·00	$\frac{7}{8}$
$\frac{13}{16}$	·91	1·83	2·74	3·65	4·57	5·48	6·39	7·31	·81	1·62	2·44	3·25	4·06	4·87	5·68	6·50	$\frac{13}{16}$
$\frac{3}{4}$	·84	1·69	2·53	3·37	4·22	5·06	5·90	6·75	·75	1·50	2·25	3·00	3·75	4·50	5·25	6·00	$\frac{3}{4}$
$\frac{11}{16}$	·77	1·55	2·32	3·09	3·86	4·64	5·41	6·19	·69	1·37	2·06	2·75	3·43	4·12	4·81	5·50	$\frac{11}{16}$
$\frac{5}{8}$	·70	1·41	2·11	2·81	3·51	4·22	4·92	5·62	·62	1·25	1·87	2·50	3·12	3·75	4·37	5·00	$\frac{5}{8}$
$\frac{9}{16}$	·63	1·26	1·90	2·53	3·16	3·80	4·42	5·06	·56	1·12	1·69	2·25	2·81	3·37	3·93	4·50	$\frac{9}{16}$
$\frac{1}{2}$	·56	1·12	1·69	2·25	2·81	3·37	3·94	4·50	·50	1·00	1·50	2·00	2·50	3·00	3·50	4·00	$\frac{1}{2}$
$\frac{7}{16}$	·40	·98	1·47	1·97	2·46	2·95	3·44	3·94	·44	·87	1·31	1·75	2·18	2·02	3·06	3·50	$\frac{7}{16}$
$\frac{3}{8}$	·42	·84	1·26	1·69	2·11	2·53	2·95	3·37	·37	·75	1·12	1·50	1·87	2·25	2·62	3·00	$\frac{3}{8}$
$\frac{5}{16}$	·35	·70	1·05	1·40	1·76	2·11	2·46	2·81	·31	·62	·94	1·25	1·56	1·87	2·18	2·50	$\frac{5}{16}$
$\frac{1}{4}$	·28	·56	·84	1·12	1·40	1·69	1·97	2·25	·25	·50	·75	1·00	1·25	1·50	1·75	2·00	$\frac{1}{4}$

Thickness of plate.	¾ inch Rivets.								⅝ inch Rivets.								Thickness of plate.
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
1	·87	1·75	2·62	3·50	4·37	5·25	6·12	7·00	·75	1·50	2·25	3·00	3·75	4·50	5·25	6·00	1
$\frac{15}{16}$	·82	1·64	2·46	3·28	4·10	4·92	5·74	6·56	·70	1·40	2·11	2·81	3·51	4·22	4·92	5·62	$\frac{15}{16}$
$\frac{7}{8}$	·77	1·53	2·30	3·06	3·83	4·59	5·36	6·12	·65	1·31	1·96	2·62	3·28	3·94	4·59	5·22	$\frac{7}{8}$
$\frac{13}{16}$	·71	1·42	2·13	2·84	3·55	4·26	4·97	5·68	·61	1·22	1·83	2·44	3·04	3·65	4·26	4·85	$\frac{13}{16}$
$\frac{3}{4}$	·66	1·31	1·96	2·62	3·28	3·93	4·59	5·25	·56	1·12	1·69	2·28	2·81	3·37	3·93	4·57	$\frac{3}{4}$
$\frac{11}{16}$	·60	1·20	1·80	2·40	3·00	3·60	4·21	4·81	·51	1·03	1·54	2·06	2·57	3·09	3·60	4·10	$\frac{11}{16}$
$\frac{5}{8}$	·55	1·09	1·64	2·19	2·73	3·28	3·83	4·38	·47	·94	1·41	1·88	2·34	2·81	3·28	3·75	$\frac{5}{8}$
$\frac{9}{16}$	·49	·98	1·48	1·96	2·46	2·95	3·44	3·94	·42	·84	1·26	1·69	2·10	2·53	2·95	3·37	$\frac{9}{16}$
$\frac{1}{2}$	·43	·87	1·31	1·75	2·18	2·62	3·06	3·50	·37	·75	1·12	1·50	1·87	2·25	2·62	3·00	$\frac{1}{2}$
$\frac{7}{16}$	·38	·76	1·15	1·53	1·91	2·30	2·68	3·06	·33	·66	·98	1·31	1·64	1·97	2·29	2·62	$\frac{7}{16}$
$\frac{3}{8}$	·32	·65	·98	1·31	1·64	1·97	2·30	2·62	·28	·56	·84	1·12	1·40	1·69	1·97	2·25	$\frac{3}{8}$
$\frac{5}{16}$	·27	·55	·82	1·09	1·36	1·64	1·91	2·18	·23	·47	·70	·94	1·10	1·40	1·64	1·87	$\frac{5}{16}$
$\frac{1}{4}$	·22	·44	·66	·87	1·09	1·31	1·53	1·75	·18	·37	·56	·75	·93	1·12	1·31	1·50	$\frac{1}{4}$

Sectional Areas of Rivet Holes in Plates of Various Thicknesses—continued.

Thickness of plates.	½ inch Rivets.								⅜ inch Rivets.								Thickness of plates.
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
1	·62	1·25	1·87	2·50	3·12	3·75	4·37	5·00	·50	1·00	1·50	2·00	2·50	3·00	3·50	4·00	1
$\frac{15}{16}$	·58	1·17	1·75	2·34	2·92	3·51	4·10	4·68	·47	·93	1·40	1·87	2·34	2·81	3·28	3·75	$\frac{15}{16}$
⅞	·55	1·09	1·64	2·18	2·73	3·28	3·82	4·37	·44	·87	1·31	1·75	2·18	2·62	3·06	3·50	⅞
$\frac{13}{16}$	·51	1·01	1·52	2·03	2·53	3·04	3·55	4·06	·41	·81	1·22	1·62	2·03	2·43	2·84	3·25	$\frac{13}{16}$
¾	·47	·93	1·40	1·87	2·34	2·81	3·28	3·75	·37	·75	1·12	1·50	1·87	2·25	2·62	3·00	¾
$\frac{11}{16}$	·43	·86	1·29	1·72	2·14	2·57	3·00	3·43	·34	·69	1·03	1·37	1·71	2·06	2·40	2·75	$\frac{11}{16}$
⅝	·39	·78	1·17	1·56	1·95	2·34	2·73	3·12	·31	·62	·94	1·25	1·56	1·87	2·19	2·50	⅝
$\frac{9}{16}$	·35	·70	1·05	1·40	1·75	2·11	2·46	2·81	·28	·56	·84	1·12	1·40	1·69	1·47	2·25	$\frac{9}{16}$
½	·31	·62	·94	1·25	1·56	1·87	2·18	2·50	·25	·50	·75	1·00	1·25	1·50	1·75	2·00	½
$\frac{7}{16}$	·27	·55	·82	1·09	1·36	1·64	1·91	2·18	·22	·44	·65	·87	1·09	1·31	1·53	1·75	$\frac{7}{16}$
⅜	·23	·47	·70	·94	1·17	1·40	1·64	1·87	·19	·37	·56	·75	·94	1·12	1·31	1·50	⅜
$\frac{5}{16}$	·19	·39	·55	·78	·97	1·17	1·36	1·56	·16	·31	·47	·62	·78	·94	1·09	1·25	$\frac{5}{16}$
¼	·16	·31	·47	·62	·78	·94	1·09	1·25	·12	·25	·37	·50	·62	·75	·87	1·00	¼

Rules for finding the area of rivets in the plate.

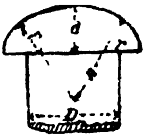
$$A=(d+\tfrac{1}{8})\,t \times \text{number of rivets} \quad \begin{cases} A = \text{area of rivets.} \\ d = \text{diameter of rivets.} \\ t = \text{thickness of plate.} \end{cases}$$

Example.—Find the area of 6, ¾″ rivets in $\frac{11}{16}$″ plate.
Area $=\frac{11}{16}\times(\frac{1}{8}+\frac{3}{4})\times 6=3{\cdot}6{\cdot}$ sq. inches.

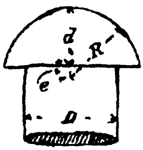
SHEARING AND BEARING VALUES OF RIVETS.

Dia. of Rivet in inches	Area in Square inches.	Shearing Value at 4 tons per sq. inch, Single Shear	Double Shear.	Bearing values at 7 tons per sq. inch. Thickness in inches of Plate passed through. $\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$
$\frac{3}{8}$	·1104	·44	·77	·66	·82	..	..	..	..	..	..	..	..
$\frac{1}{2}$	·1963	·79	1·37	·87	1·09	1·31	1·53	..	..	..	..	..	..
$\frac{5}{8}$	·3068	1·23	2·15	1·09	1·37	1·64	1·91	2·19	..	..	..	..	..
$\frac{3}{4}$	·4418	1·77	3·09	1·31	1·64	1·97	2·30	2·62	2·95	3·28	..	..	..
$\frac{7}{8}$	·6013	2·41	4·21	1·53	1·91	2·30	2·68	3·06	3·45	3·83	4·21	..	..
1	·7854	3·14	5·50	1·75	2·19	2·62	3·06	3·50	3·94	4·37	4·81	5·25	6·12

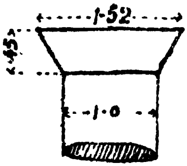
Rivet heads are of 4 kinds :—



(1) Segmental
D=diameter of rivet
R=large radius=D
r=small radius=·4 D
d=depth of head=$\frac{D}{2}$



(2) Semi circular
D=diam. of rivet=
d=depth of head=$\frac{5}{8}$ D
R=Radius=$\frac{3}{4}$D
e=$\frac{1}{2}$D.



(3) Countersunk
These rivets are placed at an angle of 60°. Depth = $\frac{3}{4}$ thickness of plate. D=1·0. Maximum 1·52.

(4) Cheese Headed Rivet :—
Depth of the head=45 D
Diameter of head=45 D

Weights and Strength of Materials.

Material. Alloys and metals.	1 Specific gravity.	2 Weight of a cubic foot.	3 Weight of a cubic inch.	4 Tensile strength per sqr. inch.	5 Crushing weight per sqr. inch.	6 Transverse stress.
		lbs.	lbs.	tons.	tons.	tons.
Aluminium Bronze 90 to 95—copper	7·68	478·4	·276	32	58	..
Brass, cast .	8·4	524·37	·3	8·	..	..
,, sheet .	8·44	526·86	·301	14·	..	..
,, wire .	8·54	533·109	·307	22·	..	..
,, 5 copper, 1 zinc	8·41	525·09	·3	13·7	..	..
,, 4 ,, 1 ,,	8·448	527·36	·304	14·7	..	..
,, 3 ,, 1 ,,	8·307	524·18	·3	13·1	..	..
,, 2 ,, 1 ,,	8·299	518·06	·299	12·5	..	..
,, 1 ,, 1 ,,	8·23	513·75	·296	9·2	..	..
,, 1 ,, 2 ,,	8·283	517·06	·298	19·3	..	..
,, 1 ,, 4 ,,	7·371	460·13	·265	1·9	..	..
Gun-metal, 10 cop., 1 tin.	8·464	528·36	·306	16·1	..	..
Gun-metal, 9 cop., 1 tin.	8·462	528·24	·305	15·2	..	..
Gun-metal, 8 cop., 1 tin.	8·459	528·05	·305	17·7	..	..
Gun-metal, 7 cop., 1 tin.	8·456	527·89	·305	13·6	..	..
Linseed oil .	·94	58	·034	..	..	..
Copper wire .	8·9	555	·32	26·	..	..
,, sheet .	8·78	548·1	·316	13·4	..	..
,, cast ..	8·607	537·3	·31	8·4	..	..
,, bolts ..	8·85	552·4	·318	17·	..	..
Gold ..	18·417	1150	·665	9·1	..	..
Iron cast ..	7 to 7·6	437 to 474·4	·252 to ·273	6 to 13	36 to 64	2 to 3·4
,, wrought ..	7·6 to 7·8	474·4 to 486·9	·273 to ·281	16 to 29	16 to 18	3 to 5
,, wire ..	..	..	..	40·	..	..
Lead cast ..	11·36	708·5	·408	·8	3·1	..
,, sheet ..	11·4	711·6	·41	1·5	..	..
Steel ..	8·	409·	·288	52·	150·	..
Tin cast ..	7·291	455·1	·262	2·0	6·7	..
Zinc cast ..	7·	437·	·252	3·3	..	..
Aluminium sheet ..	2·67	166·6	·096	12	..	..
,, cast ..	2·56	159·8	·092	8	..	

Table of Weights of Building Materials.

Matorial.	Specific Gravity.	Weight of a c. ft. in lbs.	No. of c.ft. in a ton.	Tensile strength per sq. in.	Crushing weight per sq. inch.
Lime stone ..	2·23to2·6	139 to 160	16	..	7700
Marble statuary ..	2·7	170	13·2	..	9000
Slate ..	2·5	157	16·2	..	10000
Brick common, pucca	1·6 to 2·0	120	20	..	..
Brick, sundried ..	..	100 to 110	22	..	..
Kunkar lime ..	..	72	31	..	..
White limo ..	..	36	62	..	..
Surkhi ..	..	80	28	..	..
Sand ..	1·50to1·88	100 to 110	22	..	..
Brick ballast ..	..	57	39	..	..
Stone ballast 1½″ ..	..	89	25	..	..
Dust coal (Dandot) ..	..	57	39	..	..
Steam coal (Bengal) ..	..	55	42	..	..
Charcoal ..	..	16½	136	..	..
Wood fuel ..	..	22·5	100	..	..
Lime concrete (B. Ballast.)	..	115	19·5	..	..
Lime concrete (stone Ballast).	..	140	16·5	..	..
Cement concrete ..	2·2	144 to 150	16·0	..	..
Cement, Portland ..	1·35	86	26	400 to 600	3795 to 5900
Earth ..	1·52 to 2·0	100 to 110	22	..	..
Rubber, India ..	·93	58	39	..	..
Ivory ..	1·82	114	19·7	..	..
Tar ..	1·016	63	34	..	..
Shingle ..	1·42	88	26	..	..
Tile ..	1·83	113	19·8	..	..
Clay ..	..	120 to 130	18·7	..	..
Coke ..	..	46	50	..	..
Kalka stone ..	..	164	14·5	..	..
Baghanwala stone ..	..	148	16·0	..	..
Sanjauli stone ..	..	171	13·2	..	..

Weights of Floors and Roofing Materials.

Material.	Actual weights in lbs. per sq. foot.	REMARKS.
Jack-arched roofs including 3″ of mud plaster.	150	Includes 3″ of concrete over crown of arches, but makes no allowance for workmen, etc. (see also foot-note).
Jack-arched roofs including 1½″ tiling, cement concrete or marble surfacing.	140	
First-class mud roof including ½″ boarding and a singletile.	70	Includes 6″ of earth and mud plaster. An allowance of 20 to 30 lbs. per sq. foot must also be made for workmen, etc., using the roof.
First-class mud roof including a double layer of 1¼″ tiles.	80	
Second-class mud roof including a single 2″ tile.	70	
Single Allahabad tiles including battens.	17	
Double Allahabad tiles with battens.	34	
Mangalore tiles with battens.	10	
Poilite or Eternit tiles including battens.	4	
Corrugated iron, 22 B. W. G. ..	2	Will vary with thickness of slates. Add 3 lbs. if 1″ boards are used.
Slates on battens ..	7	
9″ thatch with frame ..	10	
6″ thatch with frame ..	6½	
Venesta or pine ceiling ..	2	
Plaster ceiling on lathing ..	10	Will vary with thickness of plaster.
Plaster ceiling on wire netting..	7	

NOTES.—To the weight of a floor there must always be added the static equivalent of the anticipated live load in order to find the appropriate section of joist. This also applies to flat roofs likely to be used by a crowd, where, in any case, an allowance of at least 20 to 30 lbs. per sq. foot should be added to the actual weight.

Table of strength of wrought iron Screws.

Diam. of Screw.	No. of threads per inch.	Pitch.	Diam. at bottom of thread.	Safe working strength.	Diam. of Screw.	No. of threads per inch.	Pitch.	Diam. at bottom of thread.	Safe working strength.
Ins.	No.	Ins.	Ins.	lbs.	Ins.	No.	Ins.	Inch.	lbs.
$\frac{3}{16}$	24	·041	·136	58	2	$4\frac{1}{2}$	·222	1·716	9,280
$\frac{1}{4}$	20	·050	·186	109	$2\frac{1}{4}$	4	·250	1·966	12,200
$\frac{5}{16}$	18	·056	·241	182	$2\frac{1}{2}$	4	·250	2·180	14,920
$\frac{3}{8}$	16	·063	·295	274	$2\frac{3}{4}$	$3\frac{1}{2}$	·286	2·430	18,560
$\frac{7}{16}$	14	·071	·347	378	3	$3\frac{1}{2}$	·286	2·634	21,720
$\frac{1}{2}$	12	·083	·394	448	$3\frac{1}{4}$	$3\frac{1}{4}$	·308	2·884	26,240
$\frac{5}{8}$	11	·091	·500	817	$3\frac{1}{2}$	$3\frac{1}{4}$	·308	3·106	30,360
$\frac{3}{4}$	10	·100	·622	1,208	$3\frac{3}{4}$	3	·333	3·356	35,440
$\frac{7}{8}$	9	·111	·733	1,674	4	3	·333	3·574	40,000
1	8	·125	·840	2,217	$4\frac{1}{4}$	$2\frac{7}{8}$	·348	3·824	45,040
$1\frac{1}{8}$	7	·143	·942	2,776	$4\frac{1}{2}$	$2\frac{7}{8}$	·348	4·055	51,840
$1\frac{1}{4}$	7	·143	1·067	3,597	$4\frac{3}{4}$	$2\frac{3}{4}$	·364	4·305	58,640
$1\frac{3}{8}$	6	·167	1·192	4,148	5	$2\frac{3}{4}$	·364	4·534	60,240
$1\frac{1}{2}$	6	·167	1·286	5,220	$5\frac{1}{4}$	$2\frac{5}{8}$	·381	4·764	71,560
$1\frac{5}{8}$	5	·200	1·411	6,240	$5\frac{1}{2}$	$2\frac{5}{8}$	·381	5·014	78,280
$1\frac{3}{4}$	5	·200	1·494	6,960	$5\frac{3}{4}$	$2\frac{1}{2}$	·400	5·238	86,966
$1\frac{7}{8}$	$4\frac{1}{2}$	·222	1·619	8,240	6	$2\frac{1}{2}$	·400	5·488	94,524

Weight of Allahabad Tiles.

Double Tiling—	lbs.	oz.
1 Flat tile, dry	8	12
1 Semi-hexagonal tile, dry	5	12
1 Flat tile, wet	9	14
1 Semi-circular tile	4	14
Carried	29	4

Double tiling	lbs.	oz.
Batten (say)	4	4
Total	33	8
Single tiling		
1 Falt tile, wet	9	14
1 Semi-circular, wet	4	14
Battens (say)	2	0
Total	16	12

British Standard Whitworth's Screw Threads.

1	2	3	4	5	6	7	8
Full Diameter.	No. of Threads per Inch.	Size for Tapping.	Pitch.	Standard Depth of Thread.	Effective Diameter.	Core Diameter. (Max.)	Cross Sectional Area at Bottom of Thread.
Ins.			In.	In.	Ins.	Ins.	Sq. Ins.
1/4	20	3/16	·0500	·0320	·2180	·1860	·0272
5/16	18	1/4	·0556	·0356	·2769	·2414	·0458
3/8	16	19/64	·0625	·0400	·3350	·2950	·0683
7/16	14	23/64	·0714	·0457	·3918	·3460	·0940
1/2	12	13/32	·0833	·0534	·4466	·3933	·1215
9/16	12	15/32	·0833	·0534	·5091	·4558	·1632
5/8	11	33/64	·0909	·0582	·5668	·5086	·2032
11/16	11	37/64	·0909	·0582	·6293	·5711	·2562
3/4	10	5/8	·1000	·0640	·6860	·6219	·3038
13/16	10	11/16	·1000	·0640	·7485	·6844	·3679
7/8	9	47/64	·1111	·0711	·8039	·7327	·4216
1	8	27/32	·1250	·0800	·9200	·8399	·5540
1 1/8	7	61/64	·1429	·0915	1·0335	·9420	·6969
1 1/4	7	1 1/16	·1429	·0915	1·1585	1·0670	·8942
1 3/8	6	1 11/64	·1667	·1067	1·2683	1·1616	1·0597
1 1/2	6	1 19/64	·1667	·1067	1·3933	1·2866	1·3001
1 5/8	5	1 3/8	·2000	·1281	1·4969	1·3689	1·4718
1 3/4	5	1 1/2	·2000	·1281	1·6219	1·4939	1·7528
2	4·5	1 23/32	·2222	·1423	1·8577	1·7154	2·3111
2 1/4	4	1 15/16	·2500	·1601	2·0899	1·9298	2·9249
2 1/2	4	2 3/16	·2500	·1601	2·3399	2·1798	3·7318
2 3/4	3·5	2 13/32	·2857	·1830	2·5670	2·3841	4·4641
3	3·5	2 41/64	·2857	·1830	2·8170	2·6341	5·4496
3 1/4	3·25	2 55/64	·3077	·1970	3·0530	2·8560	6·4063
3 1/2	3·25	3 1/8	·3077	·1970	3·3030	3·1060	7·5769
3 3/4	3	3 5/16	·3333	·2134	3·5366	3·3231	8·6732
4	3	3 9/16	·3333	·2134	3·7866	3·5731	10·0272
4 1/2	2·875	4 1/16	·3478	·2227	4·2773	4·0546	12·9118
5	2·75	4 9/16	·3636	·2328	4·7672	4·5343	16·1477
5 1/2	2·625	5	·3810	·2439	5·2561	5·0121	19·7301
6	2·5	5 1/2	·4000	·2561	5·7439	5·4877	23·6521

To find Strength of T and L irons when used in roofs.

$$\text{Spacing} = \frac{k}{(\text{span})^2 \times \text{weight per squre foot,}}$$

or in other words, for any load and any span divide k given in the following tables by square of span × weight per square foot, the result will be spacing from centre to centre, on which this particular shape of T iron or L iron can be used in the position indicated in each table; for loads below given however, divide figures under different loads by square of the span and result will be the spacing.

Example.—At what distance apart can a T iron $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ be used when span=5′ and load is equal to 100 lbs. T iron to be placed thus ⊥.

The figures opposite to the given T iron and under 100 lbs. are 42·26.

$$\therefore \text{ Spacing required } = \frac{42{\cdot}26}{(5)^2} = \frac{42{\cdot}26}{25} = 1{\cdot}69' = 1\tfrac{3}{4}' \text{ nearly.}$$

Supposing the load was 60 lbs., then k being 4226.

$$\therefore \text{ Spacing} = \frac{4226}{(5)^2 \times 60} = 3' \text{ nearly.}$$

Example.—Find the dimensions for a ⊥ iron carrying 100 lbs. per sq. foot on a span of 5′, when spaced $2\frac{1}{2}'$ apart.

$$2\tfrac{1}{2} = \frac{k}{100 \times 5^2}$$

$$\therefore K = 6250 \text{ lbs.}$$

From table this gives $3'' \times 3'' \times \frac{1}{2}''$ T iron.

Example.—If we use $\frac{1}{2}''$ thick instead of $\frac{3}{8}''$, K = 4976.

$$\text{Spacings} = \frac{4976}{5^2 \times 100} = 2 \text{ feet.}$$

Table for Strengths of ⊤ irons when used in Roofs under different loads.

a	b	t	K	Distributed Load in Lbs. per Square Foot.						
				50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
in.	in.	in.								
4	4	½	14750	295·00	221·25	162·25	147·50	118·00	103·25	73·75
3	4	½	14102	282·04	211·53	155·12	141·02	112·81	98·71	70·51
4	3	½	8327	166·54	124·90	91·59	83·27	66·61	58·28	41·63
3½	3½	½	11113	222·26	166·69	122·24	111·13	88·90	77·79	55·56
3½	3½	⅜	3602	172·04	129·03	94·62	86·02	68·81	60·21	43·01
3	3	½	7813	156·26	117·19	82·94	78·13	62·50	54·69	39·06
3	3	⅜	6220	124·40	93·30	68·42	62·20	49·76	43·54	31·10
2½	2½	½	5408	108·16	81·12	59·48	54·08	43·26	37·85	27·04
2½	2½	⅜	4226	84·52	63·39	46·48	42·26	33·80	29·58	21·13
2½	2½	5/16	3600	72·00	54·00	39·60	36·00	28·80	25·20	18·00
2½	2½	¼	2945	58·90	44·47	31·39	29·45	23·56	20·61	14·72
2	2	½	3334	66·68	50·01	36·67	33·34	26·67	23·33	16·67
2	2	⅜	2622	52·44	39·33	28·84	26·22	20·97	18·35	13·11
2	2	5/16	2242	44·84	33·63	24·66	22·42	17·93	15·69	11·21
2	2	5/16	1843	36·86	27·64	20·27	18·43	14·76	12·90	9·21
1½	1½	⅜	1407	28·14	21·10	15·47	14·07	11·25	9·84	7·03
1½	1½	5/16	1209	24·18	18·13	13·29	12·09	9·67	8·46	6·04
1½	1½	¼	1000	20·00	15·00	11·00	10·00	8·00	7·00	5·00
1½	1½	3/16	777	15·54	11·65	8·54	7·77	6·21	5·43	3·88
1½	1½	⅛	538	10·76	8·07	5·91	5·39	4·30	3·76	2·69

When used in inverted position under roof thus ⊥

a	b	t	K	50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
4	4	½	11800	236·00	177·00	129·80	118·00	94·40	82·60	59·00
3	4	½	11282	225·64	169·23	123·10	112·82	90·25	78·97	56·41
4	3	½	6662	133·24	99·93	73·28	66·62	53·29	46·63	33·31
3½	3½	½	8990	179·80	134·85	98·89	89·90	71·92	62·93	44·95
3½	3½	⅜	6882	137·64	103·23	75·70	68·82	55·05	48·17	34·41
3	3	½	6250	125·00	93·75	68·75	62·50	50·00	43·75	31·25
3	3	⅜	4976	99·52	74·54	54·73	49·76	39·80	34·83	24·83

Table for strengths of T *irons when used in roofs under different loads*—continued.

a	b	t	K	50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
				DISTRIBUTED LOADS IN LBS. PER SQUARE FOOT.						
in.	in.	in.								
2½	2½	½	4326	86·52	64·89	45·58	43·26	34·60	30·28	21·63
2½	2½	⅜	3381	67·62	50·71	37·19	33·81	27·04	23·66	16·90
2½	2½	5/16	2881	57·62	43·21	31·69	28·81	23·04	20·16	14·40
2½	2½	¼	2356	47·12	35·34	25·91	23·57	18·84	16·49	11·78
2	2	½	2657	53·34	40·00	29·33	26·67	21·33	18·66	13·33
2	2	⅜	2098	41·96	31·47	·23·07	20·98	16·78	14·68	10·49
2	2	5/16	1794	35·88	26·91	19·73	17·94	14·35	12·55	8·97
2	2	¼	1474	29·48	22·11	16·21	14·74	11·79	10·31	7·37
1½	1½	⅝	1126	22·52	16·89	12·38	11·26	9·00	7·88	5·63
1½	1½	5/16	967	19·34	14·50	10·63	9·67	7·73	6·76	4·8[illegible]
1½	1½	¼	800	16·00	12·00	8·86	8·00	6·40	5·60	4·00
1½	1½	5/16	622	12·44	9·33	6·84	6·22	4·97	4·35	3·11
1½	1½	⅛	430	8·60	6·45	4·75	4·30	3·44	3·01	2·15

Table for strengths of L *irons when used in roofs under different loads* ˥.

a	b	t	K	50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
3	4	½	11062	221·24	165·93	121·68	110·62	88·49	77·43	55·31
4	4	½	10576	211·52	158·64	116·33	105·76	84·60	74·03	52·88
4	3	½	6245	124·90	93·67	68·69	62·45	49·96	43·71	31·22
3½	3½	½	8335	166·70	125·02	91·68	83·35	66·68	58·34	41·67
3½	3½	⅜	6451	129·02	96·76	70·96	64·51	51·60	45·15	32·25
3	3	½	5860	117·20	87·90	64·46	58·60	46·88	41·02	29·30
3	3	⅜	4665	93·30	69·97	51·31	46·65	37·32	32·65	23·32
2½	2½	½	4056	81·12	60·84	44·61	40·56	32·44	28·39	20·28
2½	2½	⅜	3170	63·40	47·55	34·87	31·70	25·36	22·17	15·85
2½	2½	5/16	2701	54·02	40·51	29·71	27·01	21·60	18·90	13·50
2½	2½	¼	2209	44·18	33·13	24·29	22·09	17·67	15·46	11·04
2	2½	½	2500	50·00	37·50	27·50	25·00	20·00	17·50	12·50

Table for strengths of **L** *irons when used in roofs under different loads.*- concluded.

***When used thus* ┐**

a	*b*	*t*	K	DISTRIBUTED LOADS IN LBS. PER SQUARE FOOT.						
				50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
in.	in.	in.								
2	2	$\frac{3}{8}$	1966	39·32	29·49	26·62	19·66	15·72	13·76	9·83
2	2	$\frac{5}{16}$	1682	33·64	25·23	18·50	16·82	13·45	11·77	8·41
2	2	$\frac{1}{4}$	1382	27·64	20·73	15·20	13·82	11·05	9·67	6·91
1½	1½	$\frac{3}{8}$	1055	21·10	15·82	11·60	10·55	8·44	7·38	5·27
1½	1½	$\frac{3}{16}$	908	18·16	13·62	9·98	9·08	7·26	6·35	4·54
1½	1½	$\frac{1}{4}$	750	15·00	11·25	8·25	7·50	6·00	5·25	3·75
1½	1½	$\frac{3}{16}$	583	11·66	8·74	6·41	5·83	4·66	4·08	2·91
1½	1½	$\frac{1}{8}$	403	8·06	6·04	4·43	4·03	3·22	2·82	2·01

***When used thus* L.**

a	*b*	*t*	K	50 lbs.	67 lbs.	90 lbs.	100 lbs.	125 lbs.	143 lbs.	200 lbs.
4	4	$\frac{1}{2}$	8850	177·00	132·75	97·35	88·50	70·80	61·95	44·25
3	4	$\frac{1}{2}$	8461	169·22	126·91	93·07	84·61	67·68	59·22	42·30
4	3	$\frac{7}{8}$	4996	99·92	74·94	54·95	49·96	39·96	34·97	24·98
3½	3½	$\frac{1}{2}$	6668	133·36	100·02	73·34	66·68	53·34	46·6	33·34
3½	3½	$\frac{3}{8}$	5161	103·22	77·41	56·77	51·61	41·28	36·12	25·80
3	3	$\frac{1}{2}$	4688	93·76	70·32	51·56	46·88	37·50	32·81	23·44
3	3	$\frac{3}{8}$	3732	74·64	55·98	41·05	37·32	29·85	26·12	18·66
2½	2½	$\frac{1}{2}$	3245	64·90	48·67	35·69	32·45	25·96	22·71	16·22
2½	2½	$\frac{3}{8}$	2536	50·72	38·04	27·89	25·36	20·28	17·75	12·68
2½	2½	$\frac{3}{16}$	2160	43·20	32·40	23·76	21·60	17·28	15·12	10·80
2½	2½	$\frac{1}{4}$	1767	35·34	26·50	19·43	17·67	14·13	12·36	8·83
2	2	$\frac{1}{2}$	2000	40·00	30·00	22·00	20·00	16·00	14·00	10·00
2	2	$\frac{3}{8}$	1573	31·46	23·59	17·30	15·73	12·58	11·01	7·86
2	2	$\frac{5}{16}$	1345	26·90	20·17	14·79	13·45	10·76	9·41	6·72
2	2	$\frac{1}{4}$	1106	22·12	16·59	12·16	11·06	8·84	7·74	5·53
1½	1½	$\frac{3}{8}$	844	16·88	12·66	9·28	8·44	6·75	5·90	4·22
1½	1½	$\frac{5}{16}$	725	14·50	10·87	7·97	7·25	5·80	5·07	3·62
1½	1½	$\frac{1}{4}$	600	12·00	9·00	6·60	6·00	4·80	4·20	3·00
1½	1½	$\frac{3}{16}$	466	9·32	6·99	5·12	4·66	3·72	3·26	2·33
1½	1½	$\frac{1}{8}$	323	6·46	4·84	3·55	3·23	2·58	2·26	1·16

Wooden Pillars or Posts.

The pillars are generally made square.

Rule :—Area required $= \frac{\text{Weight}}{700}$ (Deodar).

$= \frac{\text{Total weight}}{1,200}$ (Teak).

The depth should not be more than 8 times × breadth. If more, multiply the area found above, by—

(*a*)=more than		8 times and less than	12	multiply by		$\frac{6}{5}$
(*b*)	do.	12	ditto	24	ditto	2
(*c*)	do.	24	ditto	36	ditto	4
(*d*)	do.	36	ditto	48	ditto	6

Example.—The column is carrying a load of 8,000 lbs., find its dimensions For Deodar, (*b*) for Teak for length from 4 feet to 20 feet.

Deodar $= \frac{8,000}{700} = 11\frac{1}{2}''$ use $3\frac{1}{2}'' \times 3\frac{1}{2}''$ for 4′ length $= 11\frac{1}{2} \times 2 = 23$ inches, *i. e.*, $5'' \times 4\frac{1}{2}''$. Similarly find out sections for other lengths.

If it is of Sal or Teak, divide by 1,200
L=length of pillar in inches.
P= total load.
S=area of section in inches.
C=safe load per square foot.
b= least dimension.

then P=CS. When (L is less than 8b).
P=5/6 C.S. When (L lies between 8b and 12b).
P=$\frac{1}{2}$ C.S. When (L lies between 12b and 24b.)
P=$\frac{1}{4}$ C.S. When (L lies between 24b and 36b.).
P=$\frac{1}{6}$ C.S. When (L lies between 36b and 48b.)
The value of C is given below.

Safe Strains per square inch in lbs.

Strains.	Deodar.	Chir.	Teak.	Sal.	Brickwork concrete.
Tensile ..	700	700	1210	1353	..
Crushing ..	700	700	1210	1270	78

Strength of Wooden Pillars.

$\frac{\text{Length}}{\text{diam.}}=$	10	15	20	25	30	35	40	45	50
Breaking weight per sq. foot of section } tons.	120	118	115	100	90	84	80	77	75

Strength of Wooden and Iron Struts.

γ_c = Safe load in cwts. ends rounded and $R = \frac{L}{K}$

R	γ_c.	R	γ_c.	R	γ_c.	R	γ_c.
5	9·55	19	3·85	33	1·56	54	0·58
6	9·25	20	3·60	34	1·43	56	0·55
7	8·85	21	3·38	35	1·35	58	0·52
8	8·30	22	3·18	36	1·28	60	0·49
9	7·75	23	2·92	37	1·22	62	0·46
10	7·20	24	2·75	38	1·16	64	0·43
11	6·70	25	2·60	39	1·11	66	0·41
12	6·25	26	2·41	40	1·06	68	0·39
13	5·80	27	2·25	42	0·96	70	0·37
14	5·40	28	2·11	44	0·87	72	0·35
15	5·05	29	1·96	46	0·79	74	0·33
16	4·75	30	1·82	48	0·72	76	0·31
17	4·45	31	1·71	50	0·66	78	0·29
18	4·15	32	1·60	52	0·62	80	0·27

If both ends are fixed $\gamma_c = \frac{R}{2}$

If one fixed and other rounded $\gamma_c =$ average of R and $\frac{R}{2}$

Example.—Find the safe strength of a 10 feet 3″×2″ strut.
Length=10×12=120″ Least dimension=2′.

$R = \frac{120}{2} = 60$ and $\gamma_c = {\cdot}49$ cwt.

∴Safe load=3×2×·49=2·94 cwt.
If one end is fixed and other rounded

R=60 and $\frac{R}{2}=30$ from table γ_c for these=·49 and 1·82.∴ average=1·155

$\gamma_c = 2\times3\times1{\cdot}155 = 6{\cdot}93$ cwt.

Table of safe strength of pillars, posts, or struts of Teak, Sal or well seasoned Keekar or Sheesham.

Height in feet.	SIDE OF A SQUARE PILLAR IN INCHES.								
	3″	3½″	4″	4½″	5″	5½″	6″	6½″	7″
Feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs
3	48768	73728	103600	..	..	..	..	..	..
4	33792	60228	87000	119000	156500	198528	244992	..	..
5	29568	48228	72000	102000	136000	175872	220416	269952	324480
6	23424	39168	60250	86250	117120	153784	195840	243072	294912
7	18916	31750	49500	72750	100600	134400	172800	216960	266496
8	14976	26000	41250	62000	86400	116736	152448	193536	239616
9	12288	21500	35000	53500	74880	102184	134400	172032	215040
10	10400	18000	30000	45275	64890	89088	118656	153216	193152
11	8800	15650	25625	38250	56800	78336	105216	136704	173184
12	7676	13000	22250	34000	49500	69120	93312	122112	155904
13	..	11824	19200	29500	43000	59120	83328	109440	140544
14	..	10388	16900	26250	38750	54528	73496	98088	127104
15	..	..	14960	23000	34500	48368	67200	89088	115200
16	..	..	12400	20750	31250	44160	60672	80040	106368
17	..	..	..	18800	28000	39936	54912	73344	95616
18	..	..	..	16900	25600	36096	49920	66816	87168
19	..	..	..	..	23000	33024	45696	61440	80256
20	..	..	..	..	21200	29052	41856	56064	63728

Height in feet.	SIDE OF A SQUARE PILLAR IN INCHES							
	7½″	8″	8½″	9″	9½″	10″	11″	12″
Feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	352128	414720	481125	..	..	..	..	..
8	291450	348672	410112	477696	..	..	..	..
10	238080	289152	344448	406272	472320	544512	702720	881280
12	194688	240000	288384	344064	403200	469248	615552	783360
14	160512	199296	241536	290688	322560	403200	530832	691968
16	133248	166656	203520	246912	293160	347136	467348	609792
18	111744	140544	172800	210816	251904	299520	407808	537600
20	94464	119424	147840	181248	217728	259584	356726	474624
23	75264	95232	118560	145920	176640	211968	..	..
26	60672	87418	96768	119424	145536	175104	245760	333312
29	50304	76128	80256	99456	121844	146688	..	..

CAST IRON COLUMNS.

Iron columns are usually made of cast iron and hollow. No column with less than ⅜ inch thickness should be used.

Table of safe strength of iron columns in tons with both ends fixed.

Outer diam.	Thickness.	Length of cast iron columns in feet.											
		6′	8′	10′	12′	14′	16′	18′	20′	25′	30″	35′	40′
Inches	Inches.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.
3	⅜	4·7	3·26	2·3	1·7	1·3	1·0	·83	·68	·45	·32	·23	·18
,,	½	5·8	4·0	3·2	2·3	1·7	1·4	1·1	·90	·60	·42	·30	·18
3½	⅜	6·6	3·3	2·3	2·0	2·0	1·6	1·3	1·1	·71	·48	·36	·29
,,	½	8·2	5.9	5·1	3·6	2·7	2·1	1·7	1·4	·90	·64	·48	·38
,,	⅝	9·9	7·1	5·3	4·2	3·2	2·5	2·1	1·8	1·2	·80	·60	·48
4	⅜	8·7	6·1	4·5	3·5	2·7	2·3	1·9	1·6	1·0	·75	·56	·42
,,	½	10·9	8·1	6·1	4·7	3·6	3·1	2·5	2·0	1·4	1·0	·74	·56
,,	⅝	13·2	9·2	7·3	5·6	4·4	3·9	3·1	2·5	1·7	1·2	·92	·70
4½	⅜	9·7	7·4	5·7	4·4	3·6	3·0	2·5	2·0	1·3	1·0	·78	·60
,,	½	13·8	10·6	8·1	6·5	5·0	4·3	3·5	2·9	1·9	1·4	1·0	·80
,,	⅝	16·7	12·8	9·9	7·7	6·1	5·3	4·3	3·6	2·4	1·8	1·3	1·0
5	⅜	11·8	9·4	7·4	5·8	4·5	3·8	3·2	2·8	1·9	1·4	1·1	·81
,,	½	16·6	13·1	10·3	8·2	6·6	5·4	4·5	3·7	2·5	1·8	1·3	1·0
,,	⅝	20·4	16·1	12·7	9·1	8·1	6·7	5·6	4·6	3·1	2·2	1·6	1·2
6	½	..	..	..	12·6	9·5	8·7	7·3	6·2	4·3	3·1	2·4	1·8
,,	⅝	..	..	..	15·6	12·8	10·6	9·0	7·6	5·4	3·8	3·0	2·2
,,	¾	..	..	..	18·0	15·0	12·5	10·5	8·3	6·4	4·6	3·6	2·7
7	½	..	..	..	17·7	14·9	12·6	10·8	9·3	6·5	4·8	3·6	2·8
,,	⅝	..	..	..	21·9	18·5	15·6	13·3	11·4	8·1	6·0	4·5	3·5
,,	¾	..	..	..	25·8	21·7	18·4	15·7	12·6	9·0	7·2	5·4	4·2
,,	⅞	..	..	..	29·2	24·6	20·9	17·8	15·2	10·8	8·4	6·3	4·9
8	⅝	..	..	..	28·8	24·8	21·4	18·5	16·1	11·6	8·7	6·6	5·2
,,	¾	..	..	..	34·0	29·3	25·2	21·8	18·7	13·7	10·5	7·9	6·3
,,	⅞	..	..	..	39·0	33·6	29·9	25·0	21·8	16·2	12·2	9·3	7·4
,,	1	..	..	..	43·8	37·7	32·5	28·1	24·4	16·4	14·0	10·6	8·4

Table of safe strength of iron columns in tons with both ends fixed.—concluded.

Outer diam.	Thickness.	Length of cast iron columns in feet.								
		12′	14′	16′	18′	20′	25′	30′	35′	40′
Inches.	Inches	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.	Ton.
9	$\frac{5}{8}$	36·2	31·5	27·7	24·3	21·3	15·7	12·0	9·1	7·3
,,	$\frac{3}{4}$	42·8	37·2	32·7	28·7	24·2	18·4	14·4	10·9	9·9
,,	$\frac{7}{8}$	49·1	42·7	37·5	32·9	28·9	21·2	16·8	12·8	10·3
,,	1	55·3	48·7	42·3	37·1	32·6	23·0	19·2	14·6	11·8
,,	$1\frac{1}{8}$	64·2	50·8	49·0	43·0	36·3	27·6	21·6	16·4	13·2
10	$\frac{3}{4}$	50·3	44·7	39·7	37·2	31·0	23·5	18·9	14·7	11·4
,,	$\frac{7}{8}$	59·5	53·5	47·0	41·7	37·0	27·9	22·0	17·1	13·6
,,	1	67·1	59·7	53·0	47·0	41·7	31·4	25·2	19·6	15·6
,,	$1\frac{1}{8}$	71·3	63·5	56·3	49·9	44·3	33·3	28·3	22·1	17·5
,,	$1\frac{1}{4}$	81·6	72·6	64·3	57·2	50·7	38·1	31·5	24·0	19·5
11	$\frac{3}{4}$	56·4	50·9	45·7	41·0	36·8	28·2	24·0	18·9	15·3
,,	$\frac{7}{8}$	69·2	62·4	56·1	50·4	45·1	34·5	28·0	22·0	17·8
,,	1	79·1	71·4	64·2	57·6	51·6	39·5	32·0	25·2	26·4
,,	$1\frac{1}{8}$	84·6	76·4	68·6	61·5	55·2	42·3	36·0	28·3	22·9
,,	$1\frac{1}{4}$	96·5	87·1	78·2	70·2	63·0	48·3	40·0	31·5	25·5
,,	$1\frac{3}{8}$	108·7	98·1	88·2	79·2	70·9	54·3	44·0	34·6	28·1
12	$\frac{3}{4}$	68·7	62·1	57·0	51·3	46·6	36·3	29·8	23·9	19·3
,,	$\frac{7}{8}$	80·1	72·5	66·5	60·2	54·4	42·3	34·8	27·8	22·5
,,	1	91·6	82·9	76·0	68·8	62·2	48·4	39·8	31·8	25·8
,,	$1\frac{1}{8}$	98·4	89·1	81·6	73·8	66·3	51·9	44·8	35·8	29·0
,,	$1\frac{1}{4}$	111·9	101·3	92·9	83·0	73·0	52·1	49·8	39·8	32·2
,,	$1\frac{3}{8}$	114·8	104·0	95·3	86·2	78·0	60·7	54·7	43·7	35·5
,,	$1\frac{1}{2}$	131·2	118·8	108·9	98·5	89·1	69·3	59·7	47·7	38·7

Note.—For other heights or thicknesses than given above, interpolate by direct proportions.

HOLLOW COLUMNS.

The strength nearly equals the difference between that of the two solid columns, the diameters of which are equal to the external and internal diameters of the hollow one.

Let D = external diameter in inches.

d = Internal diameter in inches.

L = Length in feet.

W = Breaking strength in tons

(1) When ends are rounded and $L > 15\ D$

- For solid columns $W = 14.9 \cdot \dfrac{D^{3.76}}{L^{1.7}}$
- For hollow columns $W = 13 \cdot \dfrac{D^{3.76} - d^{3.76}}{L^{1.7}}$

(2) Ends flat $L > 30\ D$

- For solid columns $W = 14.16 \cdot \dfrac{D^{3.55}}{L^{1.7}}$
- For hollow columns $W = 44.34\ \dfrac{D^{3.55} - d^{3.55}}{L^{1.7}}$

Example.—A hollow cast iron column is 20′ long and has external diam. 4″ and carries a safe load of 2 tons. The ends are flat and fixed. Find the thickness of metal.

Let factor of safety = 10 then $W = 2 \times 10 = 20$ tons.

$$20 = W = \frac{44.34.\ D^{3.55} - d^{3.55}}{L^{1.7}} = 44.34 \frac{4^{3.55} - d^{3.55}}{20^{1.7}}$$

$$\therefore d = \sqrt[3.55]{74} = 3\tfrac{1}{4}'' \text{ nearly.}$$

$$\therefore \text{Thickness of metal} = \frac{4 - 3\frac{1}{4}}{2} = 3/8 \text{ inch.}$$

Table of safe strength of pillars, posts, or struts, of Deodar.

Height in feet.	Side of a square pillar in inches.								
	3″	3½″	4″	4½″	5″	5½″	6″	6½″	7″
Feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	28588	43008	60445	69419	..	..	..	..	..
4	10712	35133	50750	56000	91294	115808	142912	..	..
5	17248	28133	42000	49816	79338	102592	128516	157472	189280
6	13664	22848	35000	42441	68320	89705	114240	141792	171927
7	11039	18522	28875	36169	58688	78400	108000	126560	155456
8	8736	15183	24066	31213	50400	68093	88928	106996	139776
9	7168	12544	20419	26425	43686	57605	71400	100352	125440
10	6069	10500	17500	22316	37656	51968	69316	89376	112672
11	5138	9135	14952	19838	33838	45696	61376	79744	101024
12	4480	7588	12978	17206	28875	40320	51432	71232	90944
13	..	6902	11200	15316	25088	34489	48608	98840	81984
14	.	6048	9856	13417	22610	31808	45784	57218	74144
15	..	..	8729	12103	19845	28504	39200	51948	67200
16	..	..	7238	10969	18228	26460	35100	47040	62648
17	..	..	..	9856	16338	23296	32032	42784	55776
18	..	..	..	..	14938	21056	29120	38976	50848
19	..	..	..	..	13419	19264	26656	35840	46634
20	..	..	..	..	12425	17472	24416	32704	37175

Height in feet.	Side of a square pillar in inches.							
	7½″	8″	8½″	9″	9½″	10″	11″	12″
Feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	205408	241920	280656	..	..	..	..	..
8	170016	203408	239232	278656	..	..	..	..
10	138880	168672	200928	236992	275520	317632	409920	514080
12	113568	140000	168224	200704	252700	273728	359072	456960
14	93632	116256	140896	169568	188160	235200	313152	403648
16	70728	97216	118720	144032	171010	202496	272619	355712
18	65184	81984	100800	122976	146937	174728	237888	313600
20	55104	69622	86240	105728	127008	151424	208096	278614
23	43904	48552	69160	85120	103040	123648	..	..
26	35392	45024	56448	69664	84896	102144	143360	194432
29	29344	44408	46816	58016	70784	85568	..	..

$\frac{1}{5}$th Breaking Weight in tons of Cast iron solid Columns, ends flat and fixed.

Diam.	Length of Columns in feet.								
	6	8	10	12	14	16	18	20	25
Ins.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1½	·82	·50	·34	·25	·19	·15	·13	·11	·07
1¾	1·43	·87	·60	·44	·34	·27	·22	·18	·13
2	2·31	1·41	·97	·71	·55	·44	·36	·30	·20
2¼	3·52	2·16	1·48	1·08	·33	·67	·54	·46	·31
2½	5·15	3·16	2·16	1·58	1·22	·97	·80	·66	·56
2¾	7·26	4·45	3·05	2·23	1·72	1·37	1·12	·94	·64
3	9·98	6·09	4·17	3·06	2·35	1·87	1·53	1·28	·88
3½	17·29	10·60	7·26	5·32	4·10	3·26	2·67	2·23	1·53
4	27·96	17·15	11·73	8·61	6·62	5·28	4·32	3·61	2·47
4½	42·73	26·20	17·93	13·15	10·12	8·07	6·60	5·52	3·78
5	62·44	38·29	26·20	19·22	14·79	11·79	9·65	8·06	5·52
5½	88·00	53·97	36·93	27·09	20·84	16·61	13·60	11·37	7·78
6	120·4	73·82	50·51	37·05	28·51	22·72	18·60	15·55	10·64
6½	160·6	98·47	67·38	49·43	38·03	30·31	24·81	20·74	14·19
7	209·7	128·6	87·98	64·53	49·06	39·57	32·39	27·08	18·53
7½	268·8	164·8	112·8	82·73	63·66	50·73	41·53	34·72	23·76
8	339·1	207·9	142·3	104·4	80·31	64·00	52·39	43·80	29·97
8½	421·8	258·6	177·0	129·8	99·90	79·61	65·16	54·48	37·28
9	518·2	317·7	217·4	159·5	122·7	97·80	80·05	66·92	45·80
9½	622·5	396·0	264·2	193·8	149·1	118·8	97·25	81·70	55·64
10	767·2	464·3	317·7	233·1	179·3	142·9	117·0	97·79	66·92
10½	902·6	553·5	378·7	277·8	213·8	170·3	139·4	116·6	79·77
11	1067·1	654·4	447·8	328·5	252·7	201·4	164·9	137·8	94·31
11½	1252·3	767·9	525·5	385·4	296·6	236·4	193·5	161·7	110·7
12	1459·6	895·1	612·5	449·3	345·7	275·5	225·5	188·5	129·0

If length is less than 30D, then correct the strength of short columns.

If S = strength of long columns.

C = 49 × area of section.

Strength of short columns in tons $= \dfrac{C\,S}{10\,S + \frac{3}{4}C}$.

WROUGHT IRON STRUTS AND PILLARS.

They are usually made of L or T iron.

Let P = pressure in lbs.

S = area of strut in square inches.

C = Safe strength in lbs. per sq. inch.

L = Length in inches.

d = Least dimension of section.

a = a constant for wrought iron $= \frac{1}{3000}$

then $$P = \frac{S \times C}{1 + a\frac{L}{d^2}}$$

Example.—A strut of a truss is of 3″×3″ angle iron and is 10 feet long. The stress on the strut is 3 tons. To find its thickness.

$$P = \frac{S \times C}{1 + a\frac{L}{d^2}} \quad \text{or} \quad 6720 = \frac{S \times 8960}{1 + \frac{1}{3000}\left\{\frac{(120)^2}{3^2}\right.}$$

$S = 1{\cdot}2''$

Area of 3″×3″ × ¼″ = 1·2 approx.

hence the thickness = ¼″.

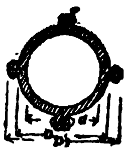
SAFE LOAD ON STRUCTURES.

Cast iron columns ..	}	
Cast iron girders for tanks ..	} = ¼	Breaking weight.
Wrought iron structures ..	}	
Cast iron for bridges and floors	= ⅙	ditto.
Stone and Bricks ..	= ⅛	ditto.
Timber live loads ..	= $\frac{1}{10}$	ditto.
Timber dead load and temporary structures ..	= ⅙	ditto.

Table of Rolled Iron segment Columns.

Thickness.	Diameters.			One Column.		Size of Rivets.
	d	D	D_1	Area of cross Section.	Wt. per ft. run.	
Ins.	Ins.	Ins.	Ins.	Sq. ins.	lbs.	
$\frac{3}{16}$	$3\frac{5}{8}$	4	$6\frac{1}{16}$	3·8	12·8	$1\frac{1}{8}\times\frac{7}{8}$
$\frac{1}{4}$	..	$4\frac{1}{8}$	$6\frac{3}{16}$	4·8	16	$1\frac{1}{4}\times\frac{7}{8}$
$\frac{5}{16}$	..	$4\frac{1}{4}$	$6\frac{6}{16}$	5·8	19·3	$1\frac{3}{8}\times\frac{7}{8}$
$\frac{3}{8}$	..	$4\frac{3}{8}$	$6\frac{7}{16}$	6·8	22·6	$1\frac{1}{2}\times\frac{7}{8}$
$\frac{1}{4}$	$4\frac{13}{16}$	$5\frac{5}{16}$	$8\frac{1}{16}$	6·4	21·3	$1\frac{5}{8}\times\frac{1}{2}$
$\frac{3}{8}$	..	$5\frac{9}{16}$	$8\frac{1}{4}$	9·2	20·6	$1\frac{3}{4}\times\frac{1}{2}$
$\frac{1}{2}$	..	$5\frac{13}{16}$	$8\frac{7}{16}$	12	40·0	$1\frac{7}{8}\times\frac{1}{2}$
$\frac{5}{8}$	..	$6\frac{1}{16}$	$8\frac{5}{8}$	14·8	49·3	$2\frac{1}{8}\times\frac{1}{2}$
$\frac{1}{4}$	$5\frac{15}{16}$	$6\frac{7}{16}$	$9\frac{1}{8}$	7·4	24·6	$1\frac{5}{8}\times\frac{1}{2}$
$\frac{3}{8}$	..	$6\frac{11}{16}$	$9\frac{5}{16}$	10·6	35·3	$1\frac{3}{4}\times\frac{1}{2}$
$\frac{1}{2}$	..	$6\frac{15}{16}$	$9\frac{1}{2}$	13·8	46	$1\frac{7}{8}\times\frac{1}{2}$
$\frac{5}{8}$	..	$7\frac{3}{16}$	$9\frac{11}{16}$	17	56·6	$2\frac{1}{8}\times\frac{1}{2}$
$\frac{1}{4}$	$7\frac{3}{16}$	$7\frac{11}{16}$	$11\frac{7}{16}$	10	33·3	$1\frac{7}{8}\times\frac{5}{8}$
$\frac{1}{2}$	..	$8\frac{1}{16}$	$11\frac{15}{16}$	18	60·0	$2\frac{1}{4}\times\frac{5}{8}$
$\frac{3}{4}$	..	$8\frac{11}{16}$	$12\frac{1}{16}$	25·2	84·0	$2\frac{5}{8}\times\frac{3}{4}$
1	..	$9\frac{3}{16}$	$12\frac{9}{16}$	33·2	110·6	$3\times\frac{3}{4}$
$1\frac{1}{4}$	..	$9\frac{11}{16}$	$12\frac{15}{16}$	41·2	137·3	$3\frac{1}{4}\times\frac{3}{4}$
$\frac{1}{4}$	11	$11\frac{1}{2}$	$15\frac{7}{16}$	16·8	56·0	$2\times\frac{3}{4}$
$\frac{1}{2}$	..	12	$15\frac{7}{8}$	26·4	88·0	$2\frac{3}{8}\times\frac{3}{4}$
$\frac{3}{4}$	..	$12\frac{1}{2}$	$16\frac{5}{16}$	37·8	126	$2\frac{3}{4}\times\frac{3}{4}$
1	..	13	$16\frac{3}{4}$	49·8	166	$3\times\frac{3}{4}$
$1\frac{1}{4}$	..	$13\frac{1}{2}$	$17\frac{3}{16}$	61·8	206	$3\frac{1}{4}\times\frac{3}{4}$
$\frac{3}{8}$	$14\frac{3}{8}$	15	$19\frac{1}{8}$	24	80	$1\frac{7}{8}\times\frac{5}{8}$
$\frac{1}{2}$	..	$15\frac{3}{8}$	$19\frac{7}{16}$	36	120	$2\frac{1}{4}\times\frac{5}{8}$
$\frac{3}{4}$	..	$15\frac{7}{8}$	$19\frac{1}{8}$	52	173·3	$2\frac{5}{8}\times\frac{3}{4}$
1	..	$16\frac{3}{8}$	$20\frac{3}{8}$	68	226·6	$3\times\frac{3}{4}$
$1\frac{3}{8}$	..	$17\frac{1}{8}$	21	92	306·6	$3\frac{3}{8}\times\frac{3}{4}$

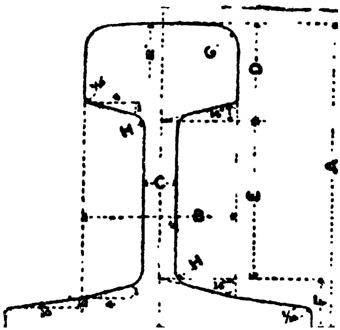
Strength of Rolled iron segment Columns.



$$\frac{5,25000}{R^2} + [30\times(1200-R)] = \text{Breaking strength.}$$

$$R = \frac{\text{Length of column.}}{\text{Least radius of column.}}$$

British Standard Sections, Flat Bottomed Rails.
(Engineering Standards Committee, 1905).



Chemical Tests.

Carbon, 0·35 to 0·5 per cent.
Manganese, 0·7 to 1·0 per cent.
Silicon, under 0·10 per cent.
Phosphorus, under 0·07 per cent.
Sulphur, under 0·07 cent. per.
Steel to be Bessemer, Martin-Siemens, or other approved process.
Drop tests to be made on 5-foot lengths.

Wt. per yard lbs.	Table of Dimensions.								Drop Tests.		
	A	B	C	D	E	F	G	H	Tup. cwts.	Cent. beargs.	Drop. feet.
20	$2\frac{1}{2}$	$1\frac{3}{8}$	$\frac{15}{64}$	$\frac{25}{32}$	$1\frac{19}{64}$	$\frac{27}{64}$	$\frac{1}{4}$	$\frac{3}{16}$	5	3	8
25	$2\frac{3}{4}$	$1\frac{1}{2}$	$\frac{17}{64}$	$\frac{29}{32}$	$1\frac{5}{16}$	$\frac{15}{32}$	,,	,,	5	3	9
30	3	$1\frac{5}{8}$	$\frac{19}{64}$	1	$1\frac{31}{64}$	$\frac{33}{64}$	,,	,,	10	3	10
35	$3\frac{1}{4}$	$1\frac{3}{4}$	$\frac{21}{64}$	$1\frac{3}{32}$	$1\frac{29}{64}$	$\frac{35}{64}$	,,	,,	10	3	$12\frac{1}{2}$
40	$3\frac{1}{2}$	$1\frac{7}{8}$	$\frac{23}{64}$	$1\frac{5}{32}$	$1\frac{49}{64}$	$\frac{37}{64}$	,,	,,	10	3	15
45	$3\frac{3}{4}$	$1\frac{31}{32}$	$\frac{25}{64}$	$1\frac{15}{64}$	$1\frac{29}{32}$	$\frac{39}{64}$	$\frac{11}{32}$	$\frac{7}{32}$	15	3	15
50	$3\frac{15}{16}$	$2\frac{1}{16}$	$\frac{13}{32}$	$1\frac{5}{16}$	$1\frac{63}{64}$	$\frac{41}{64}$	,,	,,	15	3	15
55	$4\frac{1}{8}$	$2\frac{3}{16}$	$\frac{7}{16}$	$1\frac{21}{64}$	$2\frac{3}{32}$	$\frac{43}{64}$	,,	,,	15	3	$17\frac{1}{2}$
60	$4\frac{5}{16}$	$2\frac{1}{4}$	$\frac{29}{64}$	$1\frac{13}{32}$	$2\frac{3}{16}$	$\frac{23}{32}$	,,	,,	20	3	20
65	$4\frac{7}{16}$	$2\frac{5}{16}$	$\frac{31}{64}$	$1\frac{15}{32}$	$2\frac{7}{32}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	20	3	20
70	$4\frac{5}{8}$	$2\frac{3}{8}$	$\frac{33}{64}$	$1\frac{1}{2}$	$2\frac{11}{32}$	$\frac{25}{32}$	,,	,,	20	$3\frac{1}{2}$	20
75	$4\frac{13}{16}$	$2\frac{7}{16}$	$\frac{17}{32}$	$1\frac{35}{64}$	$2\frac{29}{64}$	$\frac{13}{16}$	,,	,,	20	$3\frac{1}{2}$	20
80	5	$2\frac{1}{2}$	$\frac{35}{64}$	$1\frac{19}{32}$	$2\frac{9}{16}$	$\frac{27}{32}$	,,	,,	20	$3\frac{1}{2}$	22
85	$5\frac{3}{16}$	$2\frac{9}{16}$	$\frac{9}{16}$	$1\frac{21}{32}$	$2\frac{43}{64}$	$\frac{55}{64}$	,,	,,	20	$3\frac{1}{2}$	24
90	$5\frac{3}{8}$	$2\frac{5}{8}$	$\frac{9}{16}$	$1\frac{45}{64}$	$2\frac{25}{32}$	$\frac{57}{64}$	,,	,,	20	$3\frac{1}{2}$	26
95	$5\frac{9}{16}$	$2\frac{11}{16}$	$\frac{37}{64}$	$1\frac{3}{4}$	$2\frac{29}{32}$	$\frac{29}{32}$	,,	,,	20	$3\frac{1}{2}$	28
100	$5\frac{3}{4}$	$2\frac{3}{4}$	$\frac{37}{64}$	$1\frac{53}{64}$	3	$\frac{59}{64}$	,,	,,	20	$3\frac{1}{2}$	30

Rule for the weight of rails :—
L=greatest load on one driving wheel in tons.
v=Max. velocity in miles per hour.
W=weight of rails in lbs. per yard $=17^3 \sqrt{(L.+.00012v^2)^2}$.

Particulars of American Rail Sections.

Weight per yard.	Area.	Width of base and height.	Web.	Width of head.	Height of neutral axis x—x above base x x	Axis x—x. Moment of Inertia. I	Axis x—x. Radius of Gyration r
lbs.	Sq. Ins.	Ins.	Ins.	Ins.	Ins.		
100	9·8	5 3/4	9/16	2 3/4	2·8	43·8	2·13
95	9·3	5 9/16	9/16	2 11/16	2·7	38·6	2·06
90	8·8	5 3/4	9/16	2 5/8	2·5	34·0	1·97
85	8·3	5 3/16	9/16	2 9/16	2·5	30·0	1·90
80	7·8	5	35/64	2 1/2	2·4	26·2	1·83
75	7·4	4 11/16	17/32	2 15/32	2·4	22·9	1·78
70	6·9	4 5/8	33/64	2 7/16	2·2	19·6	1·70
65	6·4	4 7/16	1/2	2 13/32	2·2	16·9	1·63
60	5·9	4 1/4	11/24	2 3/8	2·1	14·5	1·58
55	5·4	4 1/16	15/32	2 1/4	2·0	11·9	1·49
50	4·9	3 7/8	7/16	2 1/8	1·9	9·8	1·42
45	4·4	3 11/16	27/64	2	1·8	8·0	1·35
40	3·9	3 1/2	25/64	1 7/8	1·7	6·6	1·30
35	3·4	3 1/4	23/64	1 3/4	1·6	4·8	1·19
30	3·0	3	21/64	1 5/8	1·4	3·5	1·11
25	2·5	2 3/4	19/64	1 1/2	1·3	2·4	·99
20	2·0	2 1/2	19/64	1 2/3	1·2	1·7	·92
16	1·6	2 1/4	11/64 15/64	1 1/4	1·1	1·1	·34

OUDH AND ROHILKHAND RAIL.	RAJPUTANA MALWA RAIL.	AMERICAN RAIL Section.
Weight 50 lbs. yard.	Weight 40 lbs. per yard.	

Examples of Sections in use in India are given above.

Table of safe loads on Hollow cast iron Pillars.

External diam.	Thickness of metal.	LENGTH OF PILLAR IN FEET. 8		10		12		14		16	
Inches	Inches	Ton.	Cwt.	Ton.	Cwt.	Ton.	Cwt.	Ton.	Cwt.	Ton.	Cwt.
3	½	3	17	2	18	2	8	1	6	1	1
3½	⅝	6	16	5	0	3	18	2	18	2	1
4	⅝	8	19	6	19	5	3	4	0	3	5
4½	¾	14	4	11	2	8	5	6	17	5	15
5	¾	18	6	14	4	11	3	8	16	7	2
5	1	23	2	18	2	14	4	11	5	9	1
5½	1	27	3	22	18	18	6	14	19	12	0
6	⅝	22	18	18	16	15	1	12	3	10	0
6	¾	26	18	21	19	17	19	14	15	12	0
6½	1	40	0	33	2	27	16	22	3	19	0
7	1	45	18	38	17	33	16	27	3	23	3
7	1¼	55	5	46	11	39	4	33	0	28	0
7½	1	51	18	44	5	37	18	32	0	27	0
8	1	58	0	50	3	43	6	37	3	32	0
8	1¼	70	0	60	0	51	0	45	0	38	17
8½	1	64	0	56	4	49	3	42	12	37	0
9	1	70	0	62	0	54	18	47	16	41	10
9	1¼	83	0	74	0	65	0	57	0	50	0
10	1¼	100	0	90	10	81	0	70	0	60	0

Strength of cast iron pillars or columns

W = breaking weight in tons.

A = area of section in sq. inches

$$R = \frac{D}{d} = \frac{\text{Length}}{\text{Least dimension}}$$

For solid round column $W = \dfrac{36\,A}{1+\dfrac{R^2}{400}}$

For rectangular columns $W = \dfrac{36\,A.}{1+\dfrac{R^2}{500}}$

Hollow columns of cast iron. Heigh taken only 10′; *may be safely taken* 12′.

Outside Diam.	Thickness of metal.	Weight supported.		Extent of flooring, &c., in square feet. 1½ cwt. to a ft.	2 cwt. to a ft.	3 cwt. to a ft.
Ins.	Ins.	T.	C.	Sq. ft.	Sq. ft.	Sq. ft.
3	½	3	0	40	30	20
	¾	4	10	60	45	30
	1	6	0	80	60	40
3½	½	3	15	50	37	25
	¾	6	0	80	60	40
	1	7	15	103	77	52
4	½	4	5	51	42	28
	¾	7	0	93	70	47
	1	9	10	127	95	63
4½	½	6	0	80	60	40
	¾	8	15	117	87	58
	1	11	5	150	112	75
5	½	6	10	87	65	43
	¾	9	15	130	97	65
	1	13	0	173	130	87
5½	½	7	0	93	70	47
	¾	11	5	150	112	75
	1	15	10	207	155	103
6	½	8	10	113	85	57
	¾	13	0	173	130	87
	1	17	10	233	175	117
6½	½	9	10	127	95	63
	¾	14	15	197	147	98
	1	20	0	267	200	133
7	½	10	5	137	102	68
	¾	16	0	213	160	107
	1	21	10	287	215	143

Outside Diam.	Thickness of metal.	Weight supported.		Extent of flooring, &c., in square feet. 1½ cwt. to a ft.	2 cwt. to a ft.	3 cwt. to a ft.
Ins.	Ins.	T.	C.	Sq. ft.	Sq. ft.	Sq. ft.
8	¾	18	10	247	185	123
	1	23	15	290	237	145
	1¼	27	10	367	276	183
9	¾	22	10	300	225	150
	1	26	10	353	265	177
	1¼	35	0	467	350	233
10	1	27	10	367	275	183
	1½	51	0	680	510	340
11	1	32	10	433	325	217
	1½	55	0	733	550	367
12	1	38	0	507	330	253
	1½	62	10	833	625	417
13	1	47	10	633	475	317
	1½	70	0	933	700	467
14	1	52	10	700	525	350
	1½	78	0	1040	780	520
15	1	56	10	753	565	377
	1½	85	0	1133	850	567
16	1	61	0	813	610	407
	1½	90	0	1200	900	600
17	1	65	10	873	655	437
	1½	95	0	1267	950	633
18	1	72	0	960	720	480
	1½	100	0	1333	1000	667

OLD IRON RAILS.

The rails should be given a slight camber when used over spans more than 10 feet. The camber is given in the table below and should be used by flat side upwards as shown in the figure T.

In case no camber is used the rails should be used as shown *i.e.* ⊥.

Table of Distance apart of old iron rails, broad gauge, without camber.

$$\text{Spacing} = \frac{50000}{(\text{span})^2 \times \text{weight per sq. ft.}}$$

Clear Span.	Spacing centre to centre for a distributed load per sq. foot of						
	80 lbs.	100 lbs.	120 lbs.	140 lbs.	160 lbs.	180 lbs.	200 lbs.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
10	75	60	50	43	37	33	30
11	62	50	31	35	31	28	25
12	52	42	35	30	26	23	21
13	44	36	30	25	22	18	18
14	38	31	26	22	19	17	15
15	33	27	22	19	17	15	13
16	29	23	20	17	15	13	12
17	26	21	17	16	13	12	..
18	23	19	15	13	12	..	..
19	21	17	14	12	..	..	..
20	19	15	12	..	..	..	..
21	17	14	..	..	..	..	..

Table of DISTANCE APART OF OLD IRON RAILS, *broad gauge, with camber.*

$$\text{Spacing} = \frac{65000}{(\text{Span})^2 \times \text{weight per sq. ft.}}$$

Clear Span.	Camber.	SPACING CENTRE TO CENTRE FOR THE FOLLOWING DISTRIBUTED LOADS PER SQ. FT.						
		80 lbs.	100 lbs.	120 lbs.	140 lbs.	160 lbs.	180 lbs.	200 lbs.
Ft.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
10	1	97	78	65	56	48	44	39
11	1¼	78	64	53	46	40	36	32
12	1½	68	54	45	39	34	30	27
13	1¾	58	46	38	33	29	26	23
14	2	50	40	34	29	25	22	19
15	2½	44	34	29	25	21	19	18
16	3	37	30	25	21	19	17	15
17	3½	33	27	22	19	17	15	14
18	4	30	24	20	18	16	13	12
19	4½ (19–21)	28	21	18	15	14	12	..
20		24	19	16	14	12	..	..
21		22	18	15	12	..	..	..

OLD IRON RAILS AND RAIL GIRDERS.

Rules :—

(A) Metre and Broad Gauge Rails.
W = Safe distributed load.
W = Safe load in lbs. ft. of span.
L = Length. in ft.
I = Moment of enertia.

Then

$$W=\frac{1657\cdot1\times I}{L^2\times144} \qquad (a)$$

$$w=\frac{W\times2240}{L}=\frac{25777\times I}{L^3} \qquad (b)$$

Example :—It is required to use the 60 lbs. rails on a span of 12 ft. If the weight of the roof is 100 lbs.per sq. foot. So find the spacings for rails. $I=14\cdot54$

$$W=\frac{25777\times I}{L^3}=\frac{27777\times14\cdot54}{12^3}$$

$$=217 \text{ lbs.}$$

$$\therefore \text{ Spacings }=\frac{217}{100}=2\cdot17 \text{ ft. centre to centre.}$$

Example :—Find the No. of double headed rails required for roofing a room $24'\times10'$. The weight of roof=150lbs. per sq. foot and the weight of rails=60 lbs. $I = 20\cdot71$

$$\text{then}\quad W=\frac{25777\times20\cdot71}{10\times10\times10}=534 \text{ lbs.}$$

$$\text{Spacing}=\frac{534}{150}=3\cdot56 \text{ ft.}$$

$$\text{No. of rails}=\frac{24}{3\cdot56}-1=6$$

(B) Double Rail Girders.

Let W=Safe load per foot of span.
I=Moment of inertia.
L=Length in feet.
d=depth of girder in inches.
S=Spacing in feet

$$\text{then } W=\frac{I\times11250}{L^2\times d} \text{ and } S=\frac{W}{\text{Weight of roof.}}$$

Example :—Find the spacings for a rail girder on a 20 feet span carrying a roof weighing 90 lbs. per sq. foot.

The flanges are joined together.

$L = 20'$ $I = 85\cdot3$
$d=9''$

$$W=\frac{85\cdot3\times11250}{20\times20\times9}=267 \text{ lbs.}$$

$$S=\frac{W}{90}=\frac{267}{90}=3 \text{ ft.}$$

Table of safe working loads on rails and rail girders in lbs. per ft. run of span.

..	Metre gauge, flat footed.			Broad gauge, flat footed.			Broad gauge, double-headed.	
Moment of Inertia.	5·78	31·80	25·80	14·54	85·30	94·80	20·71	106·44
Weight per yard.	40	80	80	60	120	120	60	120
Span.	Rail.	Girder, feet bolted together.	Girder heads, bolted together.	Rail.	Girder feet, bolted together.	Girder heads, bolted together.	Rail.	Girder.
Ft.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	689	..	..	..	..	..	..	..
7	431	..	..	..	..	..	..	..
8	291	..	..	732	..	..	..	..
9	204	654	531	514	..	..	732	..
10	..	530	430	375	..	..	534	..
11	..	438	355	281	..	..	401	..
12	..	368	299	216	..	..	309	..
13	..	314	254	..	631	..	243	..
14	..	270	219	..	544	608	..	678
15	..	236	191	..	474	527	..	591
16	..	207	..	..	417	463	..	520
17	..	..	..	..	369	410	..	461
18	..	..	..	..	329	366	..	410
19	..	..	..	..	295	328	..	368
20	..	..	..	..	267	296	..	332

To calculate spacings required, divide safe load given above by weight of roof, &c., per square foot.

The above weight should be reduced by 25 per cent. as the rails used are generaly worn.

Table of Rails for Rail girders over various spans to carry weight of ordinary L class Engines.

Description of rail.	Weight per yd.	Area of section, Sq. in.	Moment of Inertia.	Moment of Resistance, Tons	Maximum Bending moment and No. of Rails required for each span.																
					Maximum Bending moment.																
					66	81	98	115	134	174	201	231	276	312	348	390	432	474	500	554	613
					Spans in feet.																
					4′	5′	6′	7′	8′	9′	10′	11′	12′	13′	14′	15′	16′	17′	18′	19′	20′
F. F. Steel..	100	9·83	45·39	98·33	1	1	1	2	2	2	3	3	3	4	4	4	5	5	6	6	7
B. H. ,, ..	84	8·69	30·37	69·50	1	2	2	2	2	3	3	4	4	5	6	6	7	7	8	8	9
D. H. Iron ..	82	8·46	24·02	46·20	2	2	3	3	3	4	5	6	6	7	8	9	10	11	11	12	14
F. F. Steel ..	80	7·95	24·79	63·43	1	2	2	2	3	3	4	4	5	5	6	7	7	8	8	9	10
F. F. Steel Old Section ..	75	7·10	22·10	58·62	2	2	2	2	3	3	4	4	5	6	6	7	8	9	9	10	11
F. F. Steel New Section	75	7·40	22·35	58·12	2	2	2	2	3	3	4	4	5	6	6	7	8	9	9	10	11
D. H. Steel..	75	7·25	22·01	55·03	2	2	2	3	3	4	4	5	6	6	7	8	8	9	10	11	12
B. H. ,, ..	73	7·13	23·84	55·10	2	2	2	3	3	4	4	5	6	6	7	8	8	9	10	11	12
D. H. ,, ..	72	6·79	20·25	52·65	2	2	2	3	3	4	4	5	6	6	7	8	9	10	10	11	12
F. F. ,, ..	70	6·79	18·06	47·92	2	2	3	3	3	4	5	5	6	7	8	9	9	10	11	12	13
D. H. ,, ..	68	6·78	20·23	52·60	2	2	2	3	3	4	4	5	6	6	7	8	9	10	10	11	12
B. H. ,, ..	68	6·81	21·80	48·04	2	2	3	3	3	4	5	5	6	7	8	9	9	10	11	12	13
D. H. ,, ..	64	6·38	19·58	50·89	2	2	2	3	3	4	4	5	6	7	7	8	9	10	10	11	13
F. F. ,, ..	62	6·03	15·85	44·79	2	2	3	3	3	4	5	6	7	7	8	9	10	11	12	13	14
F. F. Iron	60	6·05	15·28	32·60	2	3	4	4	5	6	7	8	9	10	11	12	14	15	16	17	19
F. H. ,, ..	60	6·00	17·33	36·10	2	3	3	4	4	5	6	7	8	9	10	11	12	14	14	16	17
F. F. Steel..	41¼	3·82	5·82	21·60	3	4	5	6	7	9	10	11	13	15	17	19	20	22	24	26	29

To find the number of rails from the above table divide the **Maximum** bending moment by moment of resistance.

Example :—Find the number of F. F. rails at 60 lbs. per yard which will be required for a girder on a span of 8′. The load on the girder will be of ordinary L class engine.

In the above table we find for F. F. at 60 lbs.

M. R. = 32·6.

Max. B. M. on 8′ span = 134.

$\therefore$ Number of rails required $= \frac{134}{32 \cdot 6} = 4 \cdot 11.$

$\therefore$ The girder will be made of 5 rails.

Depth of metre gauge rail = $3\frac{3}{8}''$.

Depth of metre gauge rail girder = $6\frac{3}{4}''$.

Depth of broad gauge rail = $4\frac{1}{2}''$.

Depth of broad gauge rail girder = $9''$.

NOTE.—Reduce the weight by 10 per cent. for old rails. Wind pressure and moving load have not been considered.

MATHEMATICS.

Signs and Symbols in ordinary use.

$+$ Plus, addition, positive, compression.

$-$ Minus, subtraction, negative, tension.

$=$ Equal to ; as $(3)^2 = 9$

$\neq$ Unequal to.

$>$ Greater than ; as $5 > 3$

$\ngtr$ Not greater than.

$<$ Less than ; as $3 < 5$.

$\nless$ Not less than.

$\times$ Multiplied by ; as $20 \times 2 = 40$.

$\div$ Divided by ; as $20 \div 4 = 5$.

:, : :, : Ratio and proportion ; : 5 : : 9 : 15.

( ), [ ], { } Vincula or brackets denoting that all are to be taken together.

$\angle$ Angle.

$\perp$ Right angle.

$\perp$ Perpendicular.

$\parallel$ Parallel to.

$\because$ Because.

$\therefore$ Therefore.

$\triangle$ Triangle, Delta.

∞ Infinity.

$\odot$ Circle.

$\nparallel$ Not parallel to.

▱ Parallelogram.

$\frown$ Arc.

$\backsim$ Difference.

$\sqrt{\ }$ Square root.

$\propto$ Varies as.

Σ Sum of finite quantities.

π Ratio of circumference to diam.

$\sqrt[3]{\ }$ Cube root.

α Alpha.

β Beta.

γ Gamma.

θ Theta.

λ Lambda.

μ Mu.

ω Omega.

ϕ Phi.

MENTAL ARITHMETIC.

Multiplication.

(1) To multiply by 5, affix a cipher and divide by 2.

Example :— $675 \times 5 = \frac{6750}{2} = 3375$.

(2) To multiply by 25, affix two ciphers and divide by 4.

Example :— $684 \times 25 = \frac{68400}{4} = 17100$.

(3) To multiply by 75, affix two ciphers, multiply by 3 and divide by 4.

Example :— $768 \times 75 = \frac{768 \times 300}{4} = 57600$.

(4) To multiply by $12\frac{1}{2}$, affix two ciphers and divide by 8.

Example :— $684 \times 12\frac{1}{2} = \frac{68400}{8} = 8550$.

(5) To multiply by 125, affix 3 ciphers and divide by 8.

Example :— $685 \times 125 = \frac{685000}{8} = 85625$.

(6) To multiply by 250, affix 3 ciphers and divide by 4.

Example :— $763 \times 250 = \frac{763000}{4} = 190750$.

(7) To multiply by $333\frac{1}{3}$, affix 3 ciphers and divide by 3.

Example :— $683 \times 333\frac{1}{3} = \frac{683000}{3} = 227666\frac{2}{3}$.

(8) To multiply by $142\frac{2}{7}$, affix 3 ciphers and divide by 7.

Example :— $896 \times 102\frac{2}{7} = \frac{896000}{7} = 128000$.

(9) To multiply by $111\frac{1}{9}$, affix 3 ciphers and divide by 9.

Example :— $675 \times 111\frac{1}{9} = \frac{675000}{9} = 75000$.

(10) To multiply by any number of nines, for every 9, add a cipher and then subtract the multiplecand.

Example :— $6843 \times 9999 = 68430000 - 6843 = 68423157$.

(11) To multiply a number of two digits by 11, insert the sum of the two digits between them and the result is the product.

Example :— $63 \times 11 = 693$ $32 \times 11 = 352$.

When the sum of the two digits exceeds by 10 the 1 must be added to the left-hand figure.

Example :— $76 \times 11 = 836$ and $84 \times 11 = 924$.

(12) To multiply by 111.

Example ;—$768 \times 111 = 85248$

Right-hand figure will be	.. 8	=85248
Next sum of 8 and 6	.. 4	
Next sum of 8, 6, 7 with 1 carried.	2	
Next sum of 6 and 7 with 2 carried.	5	
Next 7, with 1 carried	.. 8	

(13) To multiply 33, 333, etc.

Example ;—862×33

First figure = 3 times 2 .. =6

Next = 3 (2 + 6), carrying 2 .. =4

Next = 3 (6 + 8) adding carried 2 + carrying 4 = 4

Next 3×8 adding carried 4 =28

Ans. = 28446.

(14) To multiply any number nearly 100, 1000, etc., multiply by 100, 1000 as the case may be and subtract as many times the multiplecand as the multiplier is less than 100, 1000, etc.

Example ;—68×98

$68 \times 100 = 6800$ subtract $2 \times 68 = 6800 - 136 = 6664$.

(15) To square a mixed number with $\frac{1}{2}$ for the fraction.

Example ;—Multiply $7\frac{1}{2} \times 7\frac{1}{2}$. Multiply the whole number by the figure higher than itself and add $\frac{1}{4}$

thus $7 \times 8 = 56$ add $\frac{1}{4} = 56\frac{1}{4}$ ans.

II. Division.

(1) To divide by 5, double the dividend and divide by 10.

Example :—$680 \div 5 = \frac{680 \times 2}{10} = 136.$

(2) To divide by 25, multiply by 4 and divide by 100.

Example :—$350 \div 25 = \frac{350 \times 4}{100} = 14.$

(3) To divide by 250, multiply by 4 and divide by 1000.

Example :—$875 \div 25 = \frac{875 \times 4}{1000} = 3 \cdot 5.$

III.—Squares and Square roots.

(1) To square any number of two or more digits ending with 5. The last two figures of the square are always 25, for the rest multiply the remaining figure by itself + 1.

Thus 25^2 =625 that is= 25 and 2×3
85=7225 that is 25 and 8×9
125=15625 that is 25 and 12×13 and so on.

(2) To square a number of 3 or 4 digits ending in 25. The last 3 figures in the result are always 625, to find the rest, multiply the first figure by 10 times itself+5

thus 625^2=625 and 6×65=390, 625

925^2=625 and 9×95=855, 625

(3) To square any number of two or 3 digits ending in 9 or 1, multiply the number 1 greater than that to be squared by the number 1 less, and add 1, thus

Square 39=(40×38)+1=1521
Square 51=(50×52)+1=2601

IV.—Addition.

To add the numbers from 1 to say x, add (1+x) divide by 2 and multiply the result by x

thus add 1, 2, 3, 4........to 9

(1+9)=10 divide by 2=$\frac{10}{2}$=5

Ans. 5×9=45.

General Memoranda.

	Radius.	Mass
Earth	..3960 miles.	$5{\cdot}9\times10^{21}$
Moon	..1081 „	$7{\cdot}3\times10^{19}$
Sun	..$4{\cdot}3\times10^{5}$	$1{\cdot}9\times10^{27}$

Distance of earth from sun=$9{\cdot}2\times10^7$ miles.

Distance of moon from earth=$2{\cdot}4\times10^5$ miles.

Mean solar second = $\frac{1}{86400}$ of mean solar day.

Side real day = 86164·1 mean solar seconds.

Length of second pendulum on equator=39·013 inches.

Length of second pendulum at 45° from equator=39·118 inches.

Attraction of earth=32 ft. per second=g.

MENSURATION.

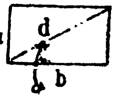
Square



Diagonal $= d = \sqrt{2} \times a$; $a = \frac{d}{\sqrt{2}}$.

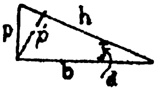
Area $= a^2 = \frac{d^2}{2}$

Rectangle



area $= ab = a\sqrt{a^2 - a^2} = b^2 \tan a = \frac{1}{2} c^2 \operatorname{Sin} 2a$

Right angled triangle

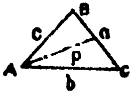


$h = \sqrt{p^2 + b^2} = b \sec a = p \operatorname{cosec} a$

Area $= \triangle = \frac{pb}{2} = \frac{hp'}{2} = \frac{b\sqrt{h^2 - b^2}}{2} = \frac{b^2}{2} \tan a$

$= \frac{bh}{2} \operatorname{Sin} a$

Triangle



$a + b + c = 2s$

$\triangle$ = area

Medians, $p, q, r,$

$p' =$ perpendicular $= \frac{2}{a}\sqrt{s(s-a)(s-b)(s-c)} = \frac{2\triangle}{a}$

$p'' =$,, $= \frac{2}{b}\sqrt{s(s-a)(s-b)(s-c)} = \frac{2\triangle}{b}$

$p''' =$,, $= \frac{2}{c}\sqrt{s(s-a)(s-b)(s-c)} = \frac{2\triangle}{c}$

Area $= \frac{1}{2} ap' = \frac{1}{2} bp'' = \frac{1}{2} cp''' = \sqrt{s(s-a)(s-b)(s-c)}$

$= \frac{1}{2} ab \operatorname{Sin} C = \frac{a^2 \operatorname{Sin} B \operatorname{Sin} C}{2 \operatorname{Sin} A}$

$= \frac{1}{3}\sqrt{2(p^2q^2 + q^2r^2 + r^2p^2) - (p^4 + q^4 + r^4)}$

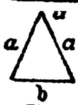
$= \frac{1}{3}\sqrt{(p+q+r)(p+q-r)(q+r-p)(r+p-q)}$

Equilateral triangle



$h = a \times \frac{\sqrt{3}}{2}$; Area $= a^2 \times \frac{\sqrt{3}}{4}$

Isosceles triangle



Area $= \frac{b}{4}\sqrt{4a^2 - b^2}$.

Parallelogram



Area $= ah = ab \operatorname{Sin} a = \frac{1}{2} d' d'' \operatorname{Sin} B$

$p = \frac{\text{area}}{d}$, If $s = \frac{a + b + d}{2}$,

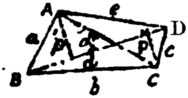
Area $= 2\sqrt{s(s-a)(s-b)(s-d)}$

Rhombus



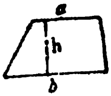
Area $= \frac{1}{2}\, d'd''$

Quadrilateral



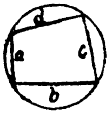
Area $= \frac{1}{2}\, d\,(p' + p'')$
$= \frac{1}{2}$ AC $\times$ BD Sin a $= \frac{1}{2}\, d'd'$ Sin a
$= \frac{1}{4}\,(b^2 - c^2 + e^2 - a^2)$ tan a

Trapezoid



Area $= \frac{1}{2}\, h\, a + b$

Quadrilateral in a Circle



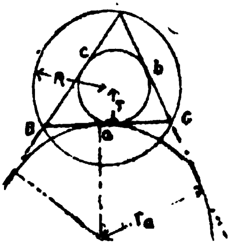
$a + b + c + d = 2s$

Area $= \sqrt{(s-a)\,(s-b)\,(s-c)\,(s-d)}$

Areas of Equilateral and Equiangular Figures.

Name of figure.	No. of sides.	Side=perpendicular ×	Perpendicular=side ×	Area=(side)² ×	Radius of outer circle=side ×	Radius of inner circle=side ×	Included angle.	Area when diameter of inscribed circle =1.
							degrees.	
Equilateral triangle	3	3·464	·289	·453	·577	·289	60	1·299
Square	4	2·00	·500	1·00	·707	·5	90	1·000
Pentagon	5	1·453	·688	1·720	·850	·688	108	·908
Hexagon	6	1·155	·864	2·598	1·0[illegible]	·866	120	·866
Septagon	7	·963	1·039	3·634	1·152	1·038	128° 34·28	·842
Octagon	8	·828	1·207	4·828	1·307	1·207	135	·828
Nonagon	9	·728	1·374	6·182	1·462	1·374	140	·818
Decagon	10	·650	1·539	7·694	1·618	1·358	144	·812
Eleven sided	11	·587	1·703	9·366	1·774	1·703	147° 16·36	·807
Twelve sided	12	·536	1·86[illegible]	11·196	1·932	1·866	150	·803

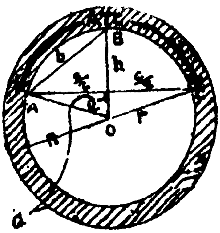
Area of triangle $= \sqrt{s(s-a)(s-b)(s-c)} = \Delta$



$r = \dfrac{\Delta}{s}$; $r_a = \dfrac{\Delta}{s-a}$; $r_b = \dfrac{\Delta}{s-b}$;

$r_c = \dfrac{\Delta}{s-c}$ $\quad R = \dfrac{abc}{4\Delta}$ $\left[s = \dfrac{a+b+c}{2} \right]$

Diameter $= 2r = \dfrac{\text{circumference}}{\pi} = D$



Circumference $= 2r\,\pi = C$

Area of circle $= r^2\,\pi = \dfrac{D^2\,\pi}{4} = \dfrac{C^2}{4\pi}$

Chord $= c = 2\sqrt{h(2r-h)} = b^2 - h^2 \times 2$

Chord of ½ arc $= b = \sqrt{\left(\dfrac{c}{2}\right)^2 + h^2} = 2\,rh$

Arc $= l = \dfrac{d}{180^\circ} \times 2\,\pi\,r = \dfrac{8b-c}{3}$ (approximately)

$= 2b + \frac{1}{3}(2b - c)$ [practical]

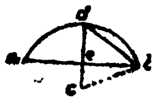
Table for finding the length of an arc when the angle at the centre and radius are given.

Rule.—Multiply the figure opposite to the given angle by the radius, the product will be the length of the arc: if there are minutes and seconds besides degrees, add together the figures opposite to degrees, minutes and seconds, and multiply the sum by the radius, the product will be the length of the arc.

Angle.	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×
Deg.		Deg.		Deg.		Deg.	
1	·0174533	13	·2268928	25	·4363323	37	·6457718
2	·0349066	14	·2443461	26	·4537856	38	·6632251
3	·0523599	15	·2617994	27	·4712389	39	·6806784
4	·0698132	16	·2792527	28	·4886922	40	·6981317
5	·0872665	17	·2967060	29	·5061455	41	·7155350
6	·1047198	18	·3141593	30	·5235988	42	·7330383
7	·1221730	19	·3316126	31	·5410521	43	·7504916
8	·1396263	20	·3490659	32	·5585054	44	·7679449
9	·1570896	21	·3665191	33	·5759587	45	·7853982
10	·1745329	22	·3839724	34	·5934119	46	·8028515
11	·1919862	23	·4014257	35	·6108652	47	·8203047
12	·2094395	24	·4188790	36	·6283185	48	·8377580
49	·8552113	60	1·0471976	71	1·2319838	81	1·4137167
50	·8726646	61	1·0646508	72	1·2566371	82	1·4311700
51	·8901179	62	1·0821041	73	1·2740904	83	1·4486233
52	·9075712	63	1·0995574	74	1·2915436	84	1·4660766
53	·9250245	64	1·1170107	75	1·3089969	85	1·4835299
54	·9424778	65	1·1344640	76	1·3264502	86	1·5009832
55	·9599311	66	1·1519173	77	1·3439035	87	1·5184364
56	·9773844	67	1·1693706	78	1·3613568	88	1·5358897
57	·9948377	68	1·1868239	79	1·3788101	89	1·5533430
58	1·0122910	69	1·2042772	80	1·3962634	90	1·5707963
59	1·0297443	70	1·2217305				

Table for finding the length of an arc when the angle at the centre and radius are given.—concld.

Angle	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×	Angle.	Length of arc in ft. =Radius ×
Mt.		Mt.		Mt.		Mt.	
1	·0002909	18	·0052360	35	·0101811	51	·0148353
2	·0005818	19	·0055269	36	·0104720	52	·0151262
3	·0008727	20	·0058178	37	·0107629	53	·0154171
4	·0011636	21	·0061087	38	·0110538	54	·0157080
5	·0014544	22	·0063995	39	·0113446	55	·0159989
6	·0017453	23	·0066904	40	·0116355	56	·0162897
7	·0020362	24	·0069813	41	·0119264	57	·0165806
8	·0023271	25	·0072722	42	·0122173	58	·0168715
9	·0026480	26	·0075631	43	·0125082	59	·0171624
10	·0029089	27	·0078540	44	·0127991	60	·0174533
11	·0031998	28	·0081449	45	·0130900	second	
12	·0034907	29	·0084358	46	·0133860	10	·0000485
13	·0037815	30	·0087266	47	·0136717	20	·0000970
14	·0040724	31	·0090175	48	·0139626	30	·0001454
15	·0043633	32	·0093084	49	·0142535	40	·0001939
16	·0046542	33	·0095993	50	·0145444	50	·0002424
17	·0049451	34	·0098902				

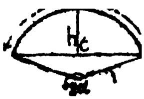


Length of arc $= L = \frac{1}{3}(8 \times c - C)$ approx.

C = chord of arc, c = chord of $\frac{1}{2}$ arc.

The above method is very approximate, to get correct results multiply by the multiplier given against Rise ÷ Chord.

Multiplier.	Rise / Chord.	Multiplier.	Rise / Chord.	Multiplier.	Rise / Chord.	Multiplier.	Rise / Chord.
1·00012	·125	1·0015	·25	1·0038	·333	1·012	·5
1·00005	·1	1·0007	.2	1·0028	.3	1·0065	·4



Area of Sector $= \frac{1}{2} lr = \frac{u}{180} \times \pi \cdot r^2$

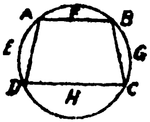
Area of Circular ring $= (R^2 + r^2)\pi = (R+r)\, t \times \pi$.

Area of Segment $= \left(\frac{h^3}{2c} + \frac{2}{3}ch\right)$ approx.

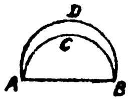
Area of segment of a circle = (*diameter*) 2 × *X*

V = Versed sine. D = Diameter.

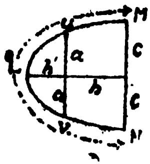
$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X	$\frac{V}{D}$	X
·01	·001329	·11	·047006	·21	·119898	·31	·207376	·41	·303187
·02	·003749	·12	·053385	·22	·128114	·32	·216666	·42	·313042
·03	·006866	·13	·059999	·23	·136465	·33	·226034	·43	·322928
·04	·010538	·14	·066833	·24	·144945	·34	·235473	·44	·332843
·05	·014681	·15	·073875	·25	·153546	·35	·244980	·45	·342783
·06	·019239	·16	·081112	·26	·162263	·36	·254551	·46	·352742
·07	·024168	·17	·088536	·27	·171090	·37	·264179	·47	·362717
·08	·029435	·18	·095135	·28	·180020	·38	·273861	·48	·372704
·09	·035012	·19	·103900	·29	·189048	·39	·283523	·49	·382700
·10	·040875	·20	·111824	·30	·198168	·40	·293370	·50	·393699



Zone ABGCDEA = Circle—Segment AFB
—Segment CHD
= 2 Segment AED + trapezoid ABCD.



Lune ACBDA = Segment ADB—Segment ACB.



L = parabolic curve $= 2 \times \sqrt{c^2 + \frac{4}{3} \times h^2}$

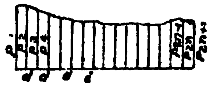
Area of parabolic segment $= 2ch \times \frac{2}{3}$ (large)

" " " $= 2\,ah' \times \frac{2}{3}$ (small).

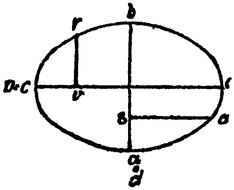
Area of zone MNVU $= \frac{4}{3}\,(ch - ah')$

$$= \frac{MN^3 - UV^3}{MN^2 - UV^2} \times \frac{2}{3}\,(h - h')$$

Simpson's Rule.



$$\text{Area} = \frac{d}{3}\left[p' + p^{2n+1} + 2\left(p^3 + p^5 + \ldots + p^{2n-3} + p^{2n-1}\right) + 4\left(p^2 + p^4 + p^5 + \ldots + p^{2n-2} + p^{2n}\right)\right]$$



$$\text{Area} = D\, d \times \frac{''}{2}$$

lengths *ru* or *sd*—

$$(cw)^2 : (ab)^2 : : cv \times vw : (rv)^2. \therefore rv = \sqrt{\frac{ab^2 \times cv \times vw}{(cw)^2}}$$

$$i.e.,\ rv = \frac{ab}{cw}\sqrt{cv \times vw}\ ;\ sd = \frac{cw}{ab}\sqrt{bs \times sa}$$

$$= \frac{\pi}{2}\left(D + d\right) = \pi\sqrt{\frac{D^2 + d^2}{2}}$$

$$= 2{\cdot}2215\sqrt{D^2 + d^2} = 2 \times \sqrt{D^2 + 1{\cdot}4674\ d^2}$$

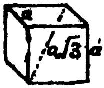
$$\text{circum} = \pi\sqrt{\frac{D^2 + d^2}{2} - \frac{(D - d)^2}{8{\cdot}8}}$$

D is less than 5*d*, if D is greater than 5*d*, divide by the number given in the margin instead of 8·8

Area of parabola : Base × ⅔ height.

D=	Div by
6*d*	9·
7*d*	9·2
8*d*	9·3
9*d*	9·35
10*d*	9·4
12*d*	9·5
14*d*	9·6
16*d*	9·68
18*d*	9·75
20*d*	9·8
25*d*	9·87
30*d*	9·92
40*d*	9·98
50*d*	10·04
	10·10
70*d*	10·17
80*d*	10·23
100*d*	10·35

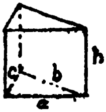
Cube



$: a^2 \times 6 =$ Surface

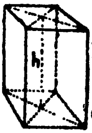
$: a \times a \times a = a^3 =$ Volume

Prism



$= (a + b + c) \times h =$ Surface

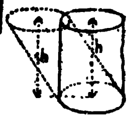
$= \triangle\, abc \times h =$ Volume



Prism

Volume base $\times\, h$

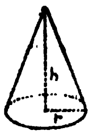
Cylinder



Surface $= 2r\pi \times h + 2r^2$.

Volume $= r^2\,\pi \times h$

Cone



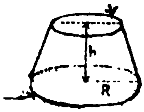
Surface = base + convexity

$= r^2\,\pi + 2\,\pi r \times \sqrt{\frac{h^2 + r^2}{2}}$

$= r^2\,\pi + \pi r \times \sqrt{r^2 + h^2}$

Volume $= r^2\,\pi \times \frac{h}{3}$

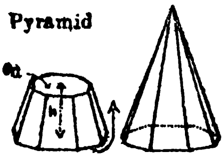
Frustum of cone
area$=a$



Area $= R^2\,\pi + r^2\,\pi + \frac{1}{2}\sqrt{h^2 + (R - r)^2}$
$\times\, 2\,\pi\,(R + r)$

Volume $= \frac{h}{3}\left(A + a + \sqrt{Aa}\right)$

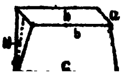
Pyramid



Volume $=$ Base $\times$ height

Surface $= A + a +$ sides

Volume $= \frac{h}{3}\left(A + a + \sqrt{a \times A}\right)$



Wedge

Volume $= \frac{2\,b + c}{3} \times a \times H$

Spheres or Globes.

Volume $= \frac{4}{3}\pi r^3 = 4{\cdot}1888\ r^2$

$= \frac{1}{6}\pi D^3 = 0{\cdot}5236\ D^3$

$= \frac{1}{6}\frac{(\text{circum.})^3}{\pi^2} = {\cdot}01689\ (\text{circum.})$

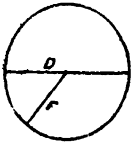
$= \frac{1}{6}\ D \times$ area of surface

$= \frac{2}{3}\ D \times$ area of great circle

$= \frac{2}{3} \times$ volume of circumscribing Cylinder

$= \frac{2}{3} \times r^2\pi \times D$

$= {\cdot}5236 \times$ volume of circumscribing cube



Area of surface $= 4\pi r^2 = \pi D_2$

$= \frac{(\text{circum.})^2}{\pi}$

$= D \times$ (circumference).

$= 4 \times$ area of great circle.

$=$ curved surface of circumscribing cylinder

$= \frac{6 \times \text{vol.}}{D}$

Particulars of Spheres.

Diam.	Surface.	Solidity.	Diam.	Surface.	Solidity.	Diam.	Surface.	Solidity.
$\frac{1}{16}$	·01227	·00013	$1\frac{3}{8}$	5·9396	1·3611	$7\frac{1}{2}$	176·71	220·89
$\frac{1}{8}$	·04909	·00102	$\frac{1}{2}$	7·0686	1·7671	8	201·06	268·08
$\frac{3}{16}$	·11045	·00345	$\frac{5}{8}$	8·2957	2·2468	$\frac{1}{2}$	226·98	321·56
$\frac{1}{4}$	·19635	·06518	$\frac{3}{4}$	9·6211	2·8062	9	254·47	381·70
$\frac{5}{16}$	·30680	·00598	$\frac{7}{8}$	11·044	3·4514	$\frac{1}{2}$	283·53	448·92
$\frac{3}{8}$	·44179	·02760	2	12·566	4·1888	10	314·16	523·60
$\frac{7}{16}$	·60132	·04385	$\frac{1}{4}$	15·904	5·9641	11	380·13	696·91
$\frac{1}{2}$	·78540	·06545	$\frac{1}{2}$	19·635	8·1813	12	452·39	904·78
$\frac{9}{16}$	·99403	·09319	$\frac{3}{4}$	23·758	10·889	13	530·93	1150·3
$\frac{5}{8}$	1·2272	·12783	3	28·274	14·137	14	615·75	1436·8
$\frac{11}{16}$	1·4849	·17014	$\frac{1}{2}$	38·484	22·449	15	706·85	1767·[illegible]
$\frac{3}{4}$	1·7671	·22089	4	50·265	33·510	16	804·25	2144·7
$\frac{13}{16}$	2·0739	·28084	$\frac{1}{2}$	63·617	47·713	17	907·93	2572·4
$\frac{7}{8}$	2·4053	·35077	5	78·540	65·450	18	1017·9	3053·6
$\frac{15}{16}$	2·7611	·43143	$\frac{1}{2}$	95·033	87·113	19	1134·1	3591·4
1	3·1416	·52360	6	113·10	113·10	20	1256·7	4188·8
$\frac{1}{8}$	3·9761	·74551	$\frac{1}{2}$	132·73	143·79	25	1963·5	8180·3
$\frac{1}{4}$	4·9088	·10227	7	153·94	179·59	30	2827·4	14137

Table of VOLUMES OF SPHERE.

Diam.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0		·0005	·004	·014	·034	·065	·11	·18	·27	·38
1	·524	·70	·90	1·15	1·44	·177	2·15	2·57	3·05	3·59
2	4·19	4·85	5·57	6·37	7·24	8·18	9·20	10·31	11·49	12·77
3	14·14	15·6	17·2	18·8	20·58	22·5	24·4	26·5	28·73	31·1
4	33·5	36·1	38·8	41·6	44·6	47·7	51·0	54·4	57·9	61·6
5	65·45	69·5	73·6	77·9	82·45	87·1	91·9	97·	102·2	107·5

'5 REGULAR SOLIDS"

Tetrahedron **Octahedron** **Lcosahedron**

Cube **Dodecahedron**

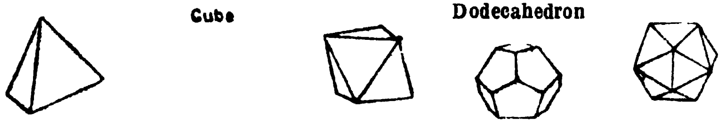
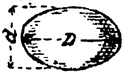
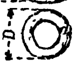
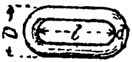


Table of VOLUMES OF EQUILATERAL AND EQUIANGULAR SOLIDS.

No. of sides.	Radius of outer circle=side ×	Radius of inner circle=side ×	Area=(side) ^{2} ×	Volume=(side)^3 ×
4	·6124	·2041	1·7320	·1178
6	·8660	·5000	6·000	1·000
8	·7071	·4082	3·4641	0·4714
12	1·4012	1·1135	20·6458	7·6631
20	·9510	·7558	8·660	2·1817

Formulæ for finding areas and volumes of Bodies, &c.

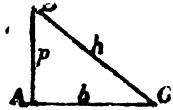
		Area.	Volume.
1		$\pi d^2 = 3{\cdot}14159\, d^2$	$\frac{\pi}{6} d^3 = {\cdot}5236\, d^3$
2		$6{\cdot}2832\, r\, h + 3{\cdot}14159 r \sqrt{r^2 - (r - h)^2}$	$2{\cdot}0944\, r^2 h$
3		$2 \pi\, r\, h = 6{\cdot}2832\, r\, h$	${\cdot}5236\, h\, (3\, r^2 \times h^2)$
4		$3{\cdot}1416 d \sqrt{\frac{D^2 + d^2}{2}}$	${\cdot}5236\, D\, d^2$
5		$\pi^2\, D\, d = 9{\cdot}87\, D\, d$	$2{\cdot}4674\, D\, d^2$
6		$\pi^2\, D\, d + 2\, \pi\, l\, d = 9{\cdot}87\, D\, d + 6{\cdot}28\, l\, d$	${\cdot}7854\, d^2 \times (3{\cdot}1416\, D + 2l)$
7		$\pi^2\, d \sqrt{\frac{T^2 + C^2}{2}} = 9{\cdot}87\, d \sqrt{\frac{T^2 + C^2}{2}}$	$2{\cdot}4674 \sqrt{\frac{T^2 \times c^2}{2}}$
8		$3{\cdot}6\, r \sqrt{r^2 + \frac{3}{4} h^2}$	$1{\cdot}5708\, r^2\, h$

1 Sphere, 2 Sector of sphere, 3 Segment of sphere, 4 Ellipsoid, 5 Ring, 6 Link 7 Elliptic link, 8 Paraboloid.

Table of multipliers for regular polygons.

No. of sides.	Name of the polygon.	Radius of the circumscribing circle, that, of the, inscribed being 1.	Side of the polygon radius of the circumscribing circle being 1.	Radius of the circumscribing circle the side being 1.	Area = side² ×
3	Trigon ..	2·000	1·732	0·577	0·433
4	Tetrogon ..	1·410	1·414	0·707	1·000
5	Pentagon ..	1·230	1·175	0·850	1·720
6	Hexagon ..	1·150	1·000	1·000	2·598
7	Heptagon ..	1·110	·867	1·152	3·633
8	Octagon ..	1·080	·765	1·306	4·828
9	Nonagon ..	1·060	·684	1·461	6·181
10	Decagon ..	1·050	·618	1·618	7·690
11	Undecagon ..	1·040	·563	1·774	9·365
12	Duodecagon ..	1·035	·517	1·931	11·196
13	Tredecagon ..	1·029	·478	2·089	13·185
14	Tetradecagon ..	1·025	·445	2·246	15·334
15	Pentadecagon ..	1·022	·415	2·404	17·642
16	Hexadecagon ..	1·019	·390	2·502	20·109
17	Heptadecagon ..	1·017	·367	2·721	22·735
18	Octadecagon ..	1·015	·347	2·879	25·526
19	Nonadecagon ..	1·013	·329	3·037	28·465
20	Elcosagon ..	1·012	·312	3·196	31·568

TRIGONOMETRY.



Sine $c = \frac{\text{perpendicular}}{\text{hypotenuse}} = \frac{p}{h}$,

Co-sine $c = \frac{\text{base}}{\text{hypotenuse}} = \frac{b}{h}$,

Tangent $c = \frac{\text{perpendicular}}{\text{base}} = \frac{p}{b}$, secant $c = \frac{\text{hypotenuse}}{\text{base}} = \frac{h}{b}$

Co-tangent $c = \frac{\text{base}}{\text{perpendicular}} = \frac{b}{p}$, co-secant $c = \frac{\text{hypotenuse}}{\text{perpendicular}} = \frac{h}{p}$

Versed sine $c = 1 - \text{co-sine } c = 1 - \frac{b}{h} = \frac{h-b}{h}$

Co-versed sine $c = 1 - \text{sine } c = 1 - \frac{p}{h} = \frac{h-p}{h}$

Supplement of an Angle A = 180°—A :—

Sin (180—A) = sin A ; cos (180 — A) = — cos A ;
Tan (180—A) = — tan A ; cot (180 — A) = — cot A ;
Sec (180—A) = — sec A ; cosec (180 — A) = cosec A ;

Complement of an Angle A = 90°—A :—

Sin (90—A) = cos A ; tan (90—A) = cot A. sec (90—A) = cosec A.

Explement of an angle A = 360—A.

Values of Trigonometrical R...

Angles.	0°	30°	45°	60°	90°	120°	135°	150°	180°
Sine ..	0	$+\frac{1}{2}$	$+\frac{1}{\sqrt{2}}$	$+\frac{3}{\sqrt{2}}$	+1	$+\frac{\sqrt{3}}{2}$	$+\frac{1}{\sqrt{2}}$	$+\frac{1}{2}$	0
Co-sine ..	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$-\frac{1}{2}$	0	$\frac{1}{2}$	$-\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	—1
Tangent ..	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	∞	$-\sqrt{3}$	—1	$-\frac{1}{\sqrt{3}}$	0
Co-tangent ..	∞	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0	$-\frac{1}{\sqrt{3}}$	—1	$-\sqrt{3}$	∞
Secant ..	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞	—2	$\sqrt{2}$	$-\frac{2}{\sqrt{3}}$	—1
Co-secant ..	∞	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞
Versin ..	0	$\frac{2-\sqrt{3}}{2}$	$\frac{\sqrt{2}-1}{\sqrt{.}}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	$\frac{\sqrt{2}+1}{\sqrt{2}}$	$\frac{2+\sqrt{3}}{2}$	2
Circular measure	$\frac{\pi}{\infty}$	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$	$\frac{2\pi}{3}$	$\frac{3\pi}{4}$	$\frac{5\pi}{6}$	π

Trigonometrical Equivalents

$$\text{Sin} = \frac{\cos}{\cot} = \frac{\tan}{\sec} = \frac{1}{\text{cosec}} = \sqrt{1-(\cos)^2} = \frac{\tan}{\sqrt{1+\tan^2}}$$

$$\text{Cos} = \frac{\sin}{\tan} = \frac{1}{\sec} = \frac{\cot}{\sec} = \sqrt{1-(\sin)^2} = \frac{1}{\sqrt{1+\tan^2}}$$

$$\text{Tan} = \frac{\sin}{\cos} = \frac{1}{\cot} = \frac{\quad}{\sqrt{1-(\sin)^2}} \; ; \; \cot = \frac{\cos}{\sin} = \frac{1}{\tan} = \frac{\text{Cos}}{\sqrt{1-(\cos)^2}}$$

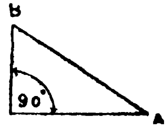
$$\text{Sec} = \frac{1}{\cos} = \frac{\tan}{\sin} = \frac{1}{\sqrt{1-(\sin)^2}} \; ; \; \text{cosec} = \frac{1}{\sin} = \frac{\cot}{\cos} = \frac{1}{\sqrt{1-(\cos)^2}}$$

$\text{Sin}^2\,\theta + \text{Cos}^2\,\theta = 1$; $\text{Sec}\,\theta \times \text{Cos}\,\theta = 1$; $\tan\theta \times \cot\theta = 1$

$\text{Sin}\,\theta \times \text{cosec}\,\theta = 1$; $1 + \tan^2\theta = \text{Sec}^2\,\theta$; $1 + \cot^2\theta = \text{cosec}^2\,\theta$

Solution of triangles.

(*a*) *Right-angled triangle.*



$BC = AB \cos B$
$= AB \sin A$
$= AC \tan A$
$= AC \cot B$

$AC = AB \sin B$
$= AB \cos A$
$= BC \tan B$
$= BC \cot A$

$AB = BC \sec B$
$= AC \sec A$
$= AC \,\text{cosec}\, B$
$= BC \,\text{cosec}\, A$

$A = 90 - B$; $B = 90 - A$; $A + B + C = 180$.

(*b*) Any triangle.

$$\frac{\text{Sin } A}{\quad} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$\tan \frac{A-B}{2} = \frac{a-b}{a+b} \tan \frac{A+B}{\quad}$$

$$\tan \quad = \frac{\quad}{(s-a)}$$

$$\text{when } r = \sqrt{\frac{(s-a)\,(s-b)\,(s-c)}{s}}$$

$$S = (a+b+c)\tfrac{1}{2}$$

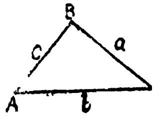
$$\cos A = \frac{c^2 + b^2 - a^2}{2bc} \quad \text{(in terms of three sides)}$$

$$\tan A = \frac{a \sin C}{b - a \cos C} = \frac{a \sin B}{c - a \cos B} \quad \text{(one angle and two sides)}$$

$$\tan A = \frac{\tan B + \tan C}{\tan B \tan C - 1} \quad [A + B + C = 180^\circ]$$

Areas of plane triangles.

$$\Delta = \frac{bc \sin A}{2} = \frac{ab \sin C}{2} = \frac{ca \sin B}{2} = r\,s.$$



$$S = \tfrac{1}{2} \text{ sum of sides} = \frac{a + b + c}{2}$$

$$\text{Area} = \sqrt{S\,(S-a)\,(S-b)\,(S-c)}$$

Properties of π

$$\pi = 3{\cdot}14159265 \qquad \sqrt[3]{\pi} = 1{\cdot}46459189$$

$$\frac{1}{\pi} = {\cdot}31830989 \qquad \frac{1}{\sqrt[3]{\pi}} = {\cdot}68278406.$$

$$\frac{\pi}{180} = {\cdot}01745329$$

$$\frac{180}{\pi} = 57{\cdot}2957795 \qquad \pi\sqrt{2} = 4{\cdot}1428829$$

$$\pi^2 = 9{\cdot}86960440 \qquad \frac{\pi}{\sqrt{2}} = 2{\cdot}2214415$$

$$\frac{1}{\pi^2} = 0{\cdot}10132118$$

$$\sqrt{\pi} = 1{\cdot}77245385 \qquad \sqrt{\frac{\pi}{2}} = 1{\cdot}2533441$$

$$\frac{1}{\sqrt{\pi}} = {\cdot}56418958 \qquad \sqrt{\frac{2}{\pi}} = {\cdot}79780$$

Table showing the use of Signs + and − in Trigonometry.

Quadrant	i	ii	iii	iv
Sine	+	+	−	−
Co-sine	+	−	−	+
Tangent	+	−	+	−
Co-tangent	+	−	+	−
Secant	+	−	−	+
Co-secant	+	+	−	−

Table of natural Sines, Co-sines, &c., to a radius 1.

NOTE.—For angles less than 45°, read from top to bottom and for those greater than 45° from bottom to top.

Degrees.	Sine.	Co-sine.	Tang.	Co-tang.	Secant.	Co-secant.	Degrees.
0	·000	1·00	·000	infinite.	1·000	infinite.	90
1	·017	·999	·017	57·29	1·0001	57·3	89
2	·035	·999	·035	28·64	1·0006	28·66	88
3	·052	·999	·052	19·08	1·0014	19·11	87
4	·070	·998	·070	14·30	1·0024	14·34	86
5	·087	·996	·087	11·43	1·0038	11·47	85
6	·105	·995	·105	9·51	1·0055	9·57	84
7	·122	·993	·123	8·14	1·0075	8·21	83
8	·137	·990	·141	7·12	1·0098	7·19	82
9	·156	·988	·158	6·32	1·0125	6·39	81
10	·174	·985	·176	5·67	1·0154	5·76	80
11	·191	·982	·194	5·14	1·0187	5·24	79
12	·208	·978	·213	4·70	1·0223	4·81	78
13	·225	·974	·231	4·33	1·0263	4·45	77
14	·242	·970	·249	4·0	1·0306	4·13	76
15	·259	·966	·268	3·73	1·0353	3·86	75
16	·276	·961	·287	3·49	1·0403	3·63	74
17	·292	·956	·306	3·27	1·0457	3·42	73
18	·309	·951	·325	3·08	1·0515	3·24	72
19	·326	·946	·344	2·90	1·0576	3·07	71
20	·342	·940	·364	2·74	1·0642	2·92	70
21	·358	·934	·384	2·61	1·012	2·79	69
22	·375	·927	·404	2·48	1·0785	2·67	68
23	·391	·921	·424	2·36	1·0863	2·56	67
24	·407	·914	·445	2·25	1·0946	2·46	66
25	·423	·906	·466	2·14	1·1033	2·37	65
26	·438	·899	·488	2·05	1·1126	2·28	64
27	·454	·891	·510	1·96	1·1223	2·20	63
28	·469	·883	·532	1·88	1·1326	2·13	62
29	·485	·875	·554	1·80	1·1434	2·06	61
30	·500	·866	·577	1·73	1·1547	2·00	60
31	·515	·857	·601	1·66	1·1666	1·94	59
32	·530	·848	·625	1·60	1·1792	1·89	58
33	·545	·839	·649	1·54	1·1924	1·84	57
34	·560	·829	·675	1·48	1·2062	1·79	56
35	·574	·819	·700	1·43	1·2207	1·74	55
Degrees.	Co-sine	Sine.	Co-tang.	Tang.	Co-secant	Secant.	Degrees.

Degrees.	Sine.	Co-sine.	Tang.	Co-tang.	Secant.	Co-secant.	Degrees.
36	·588	·809	·727	1·38	1·2361	1·70	54
37	·602	·799	·754	1·33	1·2521	1·66	53
38	·616	·788	·781	1·28	1·2690	1·62	52
39	·629	·777	·810	1·23	1·2868	1·59	51
40	·643	·766	·839	1·19	1·3054	1·56	50
41	·656	·755	·869	1·15	1·3250	1·52	49
42	·669	·743	·900	1·11	1·3456	1·49	48
43	·682	·731	·933	1·07	1·3673	1·47	47
44	·695	·719	·966	1·04	1·3902	1·44	46
45	·707	·707	1·000	1·00	1·4142	1·41	45
Degrees.	Co-sine	Sine.	Co-tang.	Tang.	Co-secant	Secant.	Degrees.

The above table gives the values of degrees of sines and co-sines only. In case the valu. for minutes is required, it should be found by proportion.

Example (1). To find the value of sines of 25° ·20′.

The above table gives 25° = ·423.

26° = ·438.

Difference = ·015 for 1°

∴ Difference for 20′ = $\frac{\cdot 20 \times \cdot 015}{60}$ = ·005

∴ Value of 25° ·20′ = ·423 + ·005 = ·428.

Example (2). To find the area of a triangle whose sides are, b = 10 and c' = 15′ and the angle subtended **A** by these 25° ·20′.

Area = ½ b c sin A = ½ × 10 × 15 × sin 25° ·20′ = 75 × ·428 = 32·1 sq. ft.

LOGARITHMS.

If $a^x = m$, then x is called the logarithm of m to the base a, or $x = \log_a m$

In all the numerical calculations the base generally taken is 10.

The tables given further on are to this base only.

Following four properties of Logarithms are very useful.

1. $\log_a (mn) = \log_a m + \log_a n$,   2. $\log_a \frac{m}{n} = \log_a m - \log_a n$

3. $\log_a m^r = r \log_a m$,   4. $\log_a \sqrt[r]{} = \frac{1}{r} \log_a$

The logarithms were originally invented to abbreviate arithmetical calculations, involving *multiplication*, *division*, *involutions* and *evolutions*, &c., as is shown by examples below.

A logarithm consists of two parts, the *integral part* is called the *characteristic*, and the fractional or decimal part, the *mantissa*. For all the numbers from 0 to 10 the characteristic is 0 ; for the numbers from 10 to 100 it is 1 ; from 100 to 1,000 it is 2 and so on.

The *mantissa* for all the numbers having the same digits, no matter where the decimal point may be, remains the same ; thus for example :—

log ·25613 = $\bar{1}$·40846, log 2·5613 = 0·40846, log 25·613 = 1·40846.

log 256·13 = 2·40846, log 2561·3 = 3·40846, log 25613 = 4·40846.

All the above logarithms have the same *mantissa* which is always positive. The characteristic changes according as the integral part changes. If the integral part is 0, the characteristics—1 or $\bar{1}$ as it is more conveniently represented; if 1, it is 0 ; if 2, it is 1, and so on, *i. e.*, the characteristic is always 1 less than the number of digits in the integral part of a number. Consequently the characteristic is always traceable at a look. It is, therefore, that the characteristic is never given in the tables ; it is always the *mantissa* which is given. For instance, to find log 312, we find the *mantissa* from tables which is ·49415, and to this we add 2 the characteristic [3 (number of integers in the number)—1] .·. log 312= 2·49415.

EXAMPLE :—Multiply 212 + 315.

Log (212 × 315) = log 212 + log 315 = 2·49831 + 2·32634 = 4·82465
Ante log of 4·82465 = 66780
.·. 212 × 315 = 66780.

EXAMPLE 2. Divide 9990 by 220

$$\text{Log}\frac{9990}{220} = \text{log } 9990 - \text{log } 220 = 3{\cdot}99957 - 2{\cdot}34635$$

Ante log = 45 = 1·65322

$$\therefore \frac{9990}{220} = 45$$

EXAMPLE 3. Find the value of $(20{\cdot}3^5)$

$\text{Log } (20{\cdot}3)^5 = 5 \text{ log } 20{\cdot}3 = 5 \times 1{\cdot}30750 = 6{\cdot}53750$

Ante log = 3447000 : (20·3) = 3447000 (approx.).

The following table has 2 numbers in the left-hand column; and the third, on top horizontal column. The last vertical column shows difference for 1, from which we can find logarithms for the 4th and 5th digits of the number as shewn in the example.

Logarithm of Numbers from 0 to 1000.

No.	0	1	2	3	4	5	6	7	8	9	Prop.
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424	..
10	00000	00432	00860	01284	01703	02119	02531	02938	03342	03743	415
11	04139	04532	04922	05308	05690	06070	06446	06819	07188	07555	379
12	07918	08279	08636	08991	09342	09691	10037	10380	10721	11059	344
13	11394	11727	12057	12385	12710	13033	13354	13672	13988	11301	323
14	14613	14922	15229	15534	15836	16137	16435	16732	17026	17319	298
15	17609	17898	18184	18469	18752	19033	19312	19590	19866	20140	281
16	20412	20683	20952	21219	21484	21748	22011	22272	22531	22789	264
17	23045	23300	23553	23805	24055	24304	24551	24797	25042	25285	249
18	25527	25768	26007	26245	26482	26717	26951	27184	27416	27646	234
19	27875	28103	28330	28556	28780	29003	29226	29447	29667	29885	222
20	30103	30320	30535	30750	30963	31175	31387	31597	31806	32015	212

Logarithm of Numbers from 0 to 1000—(continued).

No.	0	1	2	3	4	5	6	7	8	9	Prop.
21	32222	32428	32634	32838	33041	33244	33445	33646	33846	34044	202
22	34242	34439	34635	34830	35025	35218	35411	35603	35793	35984	193
23	36173	36361	36549	36736	36922	37107	37291	37475	37688	37840	135
24	38021	38202	38382	38561	38739	38917	39094	39270	39445	39620	177
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	170
26	41497	41664	41830	41996	42160	42325	42488	42651	42813	42975	164
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560	158
28	44716	44871	45025	45179	45332	45484	45637	45788	45939	46090	153
29	46240	46389	46538	46687	46835	46982	47129	47276	47422	47567	148
30	47712	47857	48001	48144	48287	48430	48572	48714	48855	48996	143
31	49136	49276	49415	49554	49693	49831	49831	50106	50243	50379	138
32	50515	50651	50786	50920	51055	51189	51189	51455	51587	51720	134
33	51851	51983	52114	52244	52375	52504	52634	52763	52892	53020	130
34	53148	53275	53403	53529	53656	53782	53908	54033	54158	54283	126
35	54407	54531	54654	54777	54900	55023	55145	55267	55388	55509	122
36	55630	55751	55871	55991	56110	56229	56348	56467	56585	56703	119
37	56820	56937	57054	57171	57287	57403	57519	57634	57749	57864	116
38	57978	58093	58206	58320	58433	58546	58659	58771	58883	58995	113
39	59106	59218	59329	59439	59550	59960	59770	59879	59988	60097	110
40	60206	60314	60423	60531	60638	60746	60853	60959	61066	61172	107
41	61278	61384	61490	61595	61700	61805	61909	62014	62118	62221	104
42	62325	62428	62531	62634	62737	62839	62941	63043	63144	63246	102
43	63347	63448	63548	63649	63749	63849	63949	64048	64147	64246	99
44	64345	64444	64542	64640	64738	64836	64933	65031	65128	65225	98
45	65322	65418	65514	65610	65706	65801	65896	65992	66087	66181	96
46	66276	66370	66464	66558	66652	66745	66839	66932	67025	67117	95
47	67210	67302	67394	67486	67578	67669	67761	67852	67943	68034	92
48	68124	68215	68305	68395	68485	68574	68664	68753	68842	68931	90
49	69020	69108	69197	69285	69373	69461	69548	69636	69723	69810	88
50	69897	69984	70070	70157	70243	70329	70415	70501	70586	70672	86
51	70757	70842	70927	71012	71096	71181	71265	71349	71433	71517	84
52	71600	71684	71767	71850	71933	72016	72099	72181	72263	72346	82
53	72428	72509	72591	72673	72754	72835	72916	72997	73078	73159	81
54	73239	73320	73400	73480	73560	73640	73719	73799	73879	73957	80
55	74036	74115	74194	74273	74351	74429	74501	74586	74663	74741	78
56	74819	74896	74974	75051	75128	75205	75282	75358	75435	75511	77
57	75587	75664	75740	75815	75891	75967	76042	76118	76193	76268	75
58	76343	76418	76492	76567	766'1	76716	76790	76864	76938	77012	74
59	77085	77159	77232	77305	77379	77452	77525	77597	77670	77743	73
60	77815	77887	77960	78032	78104	78176	78247	78319	78390	78462	72

Logarithm of Numbers from 0 to 1000—(concluded).

No.	0	1	2	3	4	5	6	7	8	9	Prop.
61	78533	78604	78675	78746	78817	78888	78958	79029	79099	79169	71
62	79239	79309	79379	79449	79518	79588	79657	79727	79796	79865	70
63	79934	80003	80072	80140	80209	80277	80346	80414	80482	80550	69
64	80618	80686	80754	80821	80889	80956	81023	81090	81158	81224	68
65	81291	81358	81425	81491	81558	81624	81690	81757	81823	81889	67
66	81954	82020	82086	82151	82217	82282	82347	82413	82478	82543	66
67	82607	82672	82737	82802	82866	82930	82995	83059	83123	83187	64
68	83251	83315	83378	83442	83506	83569	83632	83696	83759	83822	63
69	83885	83948	84011	84073	86136	84198	84261	84323	84386	84448	63
70	84510	84572	84634	84696	84757	84819	84880	84942	85003	85065	62
71	85126	85187	85248	85309	85370	85431	85491	85552	85612	85673	61
72	85733	85794	85854	85914	85974	86034	86094	86153	86213	86273	60
73	86332	86392	86451	86510	86570	86629	86688	86747	86806	86864	59
74	86923	86982	87040	87099	87157	87216	87274	87332	87390	87448	58
75	87506	87564	87622	87680	87737	87795	87852	87910	87967	88024	57
76	88081	88138	88196	88252	88309	88366	88423	88480	88536	88593	57
77	88649	88705	88762	88818	88874	88930	88986	89042	89098	89154	56
78	89209	89265	89321	89376	89432	89487	89542	89597	89653	89708	55
79	89763	89818	89873	89927	89982	90037	90091	90146	90209	90255	54
80	90309	90363	90417	90472	90526	90580	90634	90687	90741	90795	54
81	90849	90902	90956	91009	91062	91116	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91593	91645	91698	91751	91803	91855	53
83	91908	91960	92012	92065	92117	92169	92221	92273	92324	92376	52
84	92428	92480	92531	92583	92634	92686	92737	92788	92840	92891	51
85	92942	92993	93044	93095	93146	93197	93247	93298	93349	93399	51
86	93450	93500	93551	93601	93651	93702	93752	93802	93852	93902	50
87	93952	94002	94052	94101	94151	94201	94250	94300	94349	94399	49
88	94448	94198	94547	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94988	95036	95085	95134	95182	95231	95279	95328	95376	48
90	95424	95472	95521	95569	95617	95665	95713	95761	95809	95856	48
91	95904	95952	95999	96047	96095	96142	96190	96237	96284	96332	48
92	96379	96426	96473	96520	96567	96614	95661	96708	96755	96802	47
93	96848	96895	96942	96988	97035	97081	97128	97174	97220	97267	47
94	97313	97359	97405	97451	97497	97543	97589	97635	97681	97727	46
95	97772	97818	97804	97909	97955	98000	98046	98091	98137	98182	46
96	98227	98272	98318	98363	98408	98453	98498	98543	98588	98632	45
97	98677	98722	98767	98811	98856	98900	98945	98989	99034	99078	45
98	99123	99167	99211	99255	99300	99344	99388	99432	99476	99520	44
99	99564	99607	99651	99695	99739	99782	99826	99870	99913	99957	44

As explained above, when the number is less than unity, its logarithm has negative characteristic, as

log ·315=$\bar{1}$·49831

But in trigonometrical functions the negatives are avoided by adding 10 to the characteristic. The above will be written, as

Log ·315=9·49831

Logarithms thus increased are generally termed as *Tabular logarithms*, so that

Tabular logarithm=true logarithm+10.

The following table gives logarithmic sines and co-sines of all the angles from 0° to 90°. These are all tabular logarithms. Logs can also be determined for any part of a degree.

Log (sine 10°)=9·23967   Log (sine 11°)=9·28060

Difference for a degree=4093   Difference for 20=1364

Log (sine 10° 20′)=9·25331

If log (tan) be required, that is easy to derive from the tables.

$$\text{Log } (\tan 10^\circ) = \text{Log } \frac{\sin 10^\circ}{\cos 10^\circ} = \text{Log } (\sin 10^\circ) - \text{Log } (\text{co-sine } 10^\circ) + 10$$

$$= 9{\cdot}23967 - 9{\cdot}99335 + 10 = 9{\cdot}24632$$

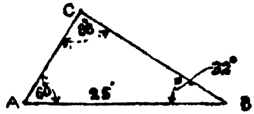
10 is added to make it *tabular*.

Logrithmic sines and cosines.

Deg.	Sine.	Cosine.	Deg.	Deg.	Sine.	Cosine.				Cosine.	Deg.
0	Inf. Neg.	10·00000	90								
1	8·24186	9·99993	89	16	9·44034	9.98284	74	31	9·71184	9·93307	59
2	8·54282	9·99974	88	17	9·46594	9.98060	73	32	9·72421	9·92842	58
3	8·71880	9·99940	87	18	9·48998	9.97821	72	33	9·73611	9·92359	57
4	8·84358	9 99894	86	19	9·51264	9.97567	71	34	9 74756	9·91867	56
5	8·94030	9·99834	85	20	9·53405	9.97299	70	35	9·75859	9·91336	55
6	9·01923	9·99761	84	21	9·55433	9.97015	69	36	9·76922	9·90796	54
7	9·08589	9·99675	83	22	9·57358	9.96717	68	37	9·77946	9·90235	53
8	9·14356	9·99575	82	23	9·59188	9.96403	67	38	9·78934	9·89653	52
9	9·19433	9·99462	81	24	9·60931	9.96073	66	39	9·79887	9·89050	51
10	9·23967	9·99335	80	25	9·62595	9.95728	65	40	9·80807	9·88425	50
11	9·28060	9·99195	79	26	9·64184	9.95366	64	41	9·81694	9·87778	49
12	9·31788	9·99040	78	27	9·65705	9.94988	63	42	9·82551	9·87107	48
13	9·35209	9·98872	77	28	9·67161	9.94593			9·83378	9·86413	47
14	9·38368	9·9869[illegible]	76	29	9·68557	9.94182			9·84177	9·85693	46
15	9·41300	9·98494	75	30	9·69897	9.93753			9 84949	9·84949	45
Deg.	Co-sine.	Sine.	Deg.	Deg.	Cosine.	Sine.	Deg.		Cosine.	Sine.	

Example :—

Side of Triangle = 25′ and angles 32° and 88°. Find area.



$$\text{Area} = \frac{c^2 \text{ Sin A Sin B}}{2 \text{ Sin C}}$$

$$= \frac{(25)^2 \text{ Sin } 60° \text{ Sin } 32°}{2 \text{ Sin } 88°}$$

$\log 2\triangle = 2 \log 25 + \text{L Sin } 60° + \text{L Sin } 32° - \text{L Sin } 88° - 10$

$= 2{\cdot}79588 + 9{\cdot}93753 + 9{\cdot}72421 - 9{\cdot}99974 - 10$

$= 2{\cdot}45788 = \log 287.$

$2\triangle = 287 \qquad \therefore \qquad = 143{\cdot}5$ sq. ft.

$$\text{Side AC} = \frac{\text{C Sin } 32°}{\text{Sin } 88°} = \frac{25 \text{ Sin } 32°}{\text{Sin } 88°}$$

$\log \text{AC} = \log 25 + \text{L Sin } 32 - \text{L Sin } 88$

$= 1{\cdot}39794 + 9{\cdot}72421 - 9{\cdot}99974 = 1{\cdot}12241 = \log 13{\cdot}26$

$\therefore$ AC $= 13{\cdot}26$ ft.

Similarly BC $= 21{\cdot}66$ ft.

PRACTICAL GEOMETRY

CONSTRUCTIONS.

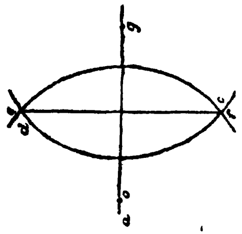


Fig. 7

To divide a given line, *ab*, into two equal Parts.

From its ends *a* and *b* as centres, and with any radius greater than one-half of *ab*, describe the arcs *c* and *d*, and join *ef*. If the line *a b* is very long, first lay off equal dista nces, *ao* and *bg*, each way from the ends, so as to approach conveniently near to each other ; and then proceed as if *og* were the line to be divided. Or measure *ab* by a scale, and thus ascertain its centre.

To divide a given line, *mn*, into any given number of equal parts.

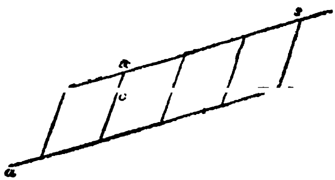


Fig. 8

From *m* and *n* draw any two parrallel lines, *mo* and *na*, to an indefinite distance, and on them from *m* and *n*, step off the required number of equal parts of any convenient length ; finally, join the corresponding points thus stepped off. Or only one line, as *mo*, may be drawn and stepped off, as to *s* ; then join *sn* ; and draw the other short lines parallel to it.

To divide a given line, *mn*. into two parts which shall have a given proportion to each other.

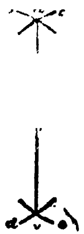


Fig. 9

This is done on the same principle as the last ; thus, let the proportion be as 1 to 3. First draw any line, *mo*, and with any convenient opening of the dividers make *mx* equal to one step—and *xs* equal to three steps. Join *sn* ; and parallel to it draw *xc*. Then *mc* is to *cn* as 1 is to 3.

From any given point, *p* on a line, *st*, to draw a perpendicular, *pa*.

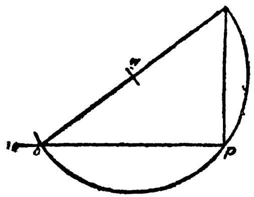


FIG. 8.

From *p*, with any convenient opening of the dividers, step off the equals *po*, *pg*. From *o* and *g* as centres, with any opening greater than half *og*, describe the two short arcs *b* and *c*, and join *ap*. Or, still better, describe four arcs, and join *ay*.

Or from *p* with any convenient scale describe two short arcs, *g* and *c*, one of them with a radius 3, and the other with a radius 4. Then from *g*, with a radius 5, describe the arc *b*. Join *pa*.

If the point p *is at one end of the line, or very near it,* extend the line, if possible, and proceed as above. But if this cannot be done, then from any convenient point, *w*, open the dividers to *p*, and describe the semicircle *spo* ; through *ow* draw *ows* ; join *ps*.

Or use the foregoing process with radii 3, 4 and 5.

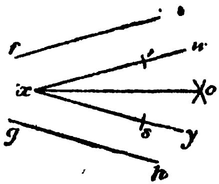


FIG. 11

To bisect or divide any angle, *wxy*, into two equal parts.

From *x* set off any two equal distances, *xr*, *xs*. From *r* and *s*, with any radius, describe two arcs intersecting, as at *o*, and join *ox*. If the two sides of the angle do not meet, as *cf* and *gh*, either first, extend them until they do meet, or else draw lines *xw* and *xy*, parallel to them—and at equal distances from them, so as to meet ; then proceed as before.

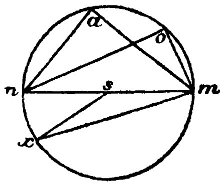


FIG 12

Angles at the circumference of a Semicircle.

All angles, as *nam*, *nom* at the circumference of a semicircle, and standing on its diameter, *nm*, are right angles ; or, as it is usually expressed, *all angles in a semicircle are right angles.* An angle *nsx*— at the centre of a circle, is twice as great as an angle, *nmx*, at the circumference, when both stand upon the same arc, *nx*.

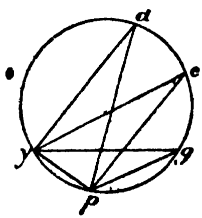


FIG. 13

Angles at the Circumference of a Circle.

All angles, as *ydp*, *yep*, *ygp*, at the circumference of a circle, and standing upon the same arc, as *yp* are equal to each other ; or, as usually expressed, *all angles in the same segment of a circle are equal.*

Angles in a Parallelogram.

A parallelogram is any four-sided straight-lined figure whose opposite sides are equal, as *abcd*; or a square, &c. Any line drawn across a parallelogram between two opposite angles is called a *diagonal*, as *ac* or *bd*. A diagonal divides a parallelogram into two equal parts, as does also any line. *mn*, drawn through the centre of either diagonal; and, moreover, the line *mn* itself is divided into two equal parts by the diagonal. Two diagonals bisect each other; they also divide the parallelogram into four angles of equal area. The sum of the two angles at the ends of any one side is $=180°$; thus, $dab+abc=abc+bcd=180°$; and the sum of the four angles, $dab, abc, bcd, cda=360°$.

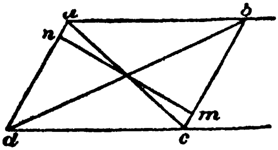
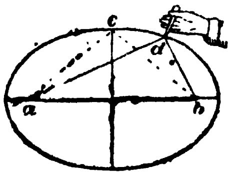


FIG 14

The sum of the squares of the four sides is equal to the sum of the squares of the two diagonals.

To Construct an Ellipse.



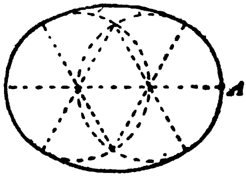


FIG. 16.

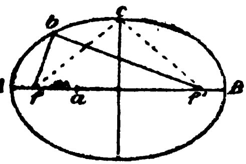


FIG. 17.

(1) Having given the two axes, fig. 15, set off from *c* half the great axis at *a* and *b*, which are the two foci in the ellipse. Take an endless string as long as the three sides in the triangle *abc*, fix two pins or nails in the foci, one in *a* and one in *b*, lay the string round *a* and *b*, stretch it with a pencil, *d*, which then will describe the desired ellipse.

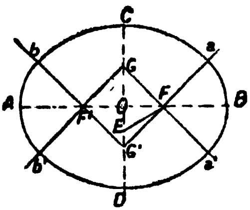


FIG 18

(2) Divide the long axis, fig. 16, into three equal parts, draw the two circles, and where they intersect one another are the centres for the tangent arcs of the ellipse, as shown by the figure.

(3) Given the two axes, fig. 17, set off half the long axis from *c* to *ff'*, which will be the two foci in the ellipse. Divide the long axis into any number of parts, say *a* to be a division point. Take A *a* as radius and *f* as centre, and describe a circle arc about *b*; take *a* B as radius and *f* as centre, describe

another circle arc about b; then the intersection b is a point in the ellipse, and so the whole ellipse can be constructed.

(4) Let A B, C D, fig. 18, be the major and minor axes of an ellipse with centre at O.

1. With distance A O cut off C E on C D. 2. From E at 60° with C E, draw EF. 3. From F at 45°, draw diagonal lines.

Then from G as a centre strike the arc a' D b', and from G′ strike the arc a C b; also from F strike the arc a A a', and from F′ strike the arc b B b'; then the figure will be very approximately an ellipse provided the ratio of the major to the minor axis is not greater than 3·2.

(*D. A. Coates, 'The Engineer,' October* 13, 1911).

To Construct a Cycloid.

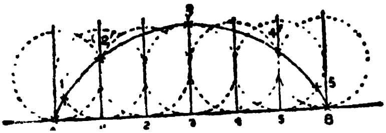


Fig. 19.

On the line AB lay off many points 1, 2, 3, 4, &c.; draw perpendicular lines at each point, and on each describe circles equal to the generating circle.

On the circum. of the circle at 1 lay off 1·1′=A. 1.
,, ,, 2 lay off 2·2′=A. 2.
,, ,, 3 lay off 3·3′=A. 3.

and so on: the points 1′,2′,4′,4′,5′ are points of the curve.

In a given Circle to inscribe any Regular Polygon.

Helix.

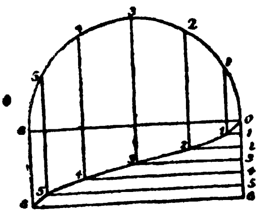


FIG. 20

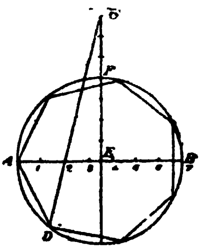


FIG. 21.

Draw the diameter, AB; from E, the centre, erect the perpendicular, EFC, cutting the circle at F. Divide EF into four equal parts, and set three parts from F to C. Divide the diameter, AB, into as many equal parts as the polygon is required to have sides. From C, through the second division in the diameter, draw CD. Join Ad; it will be the side of the polygon required.

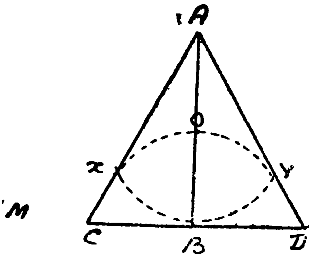


Fig. 21.

To describe an Equilateral triangle of a given height A. B.

Bisect AB in O. With O and B as centres and BO radius describe arcs cutting each other at *x* and *y*. Join *ax* and *ay* and produce to meet MN, drawn perpendicular to AB, in C and D. Then ACD will be the required equilateral triangle.

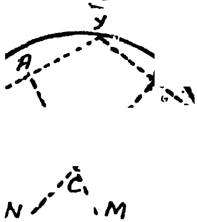


Fig. 22

To find the centre of a circle of which an arc only is given.

Let *xyz* be the given arc, *x* and *z* being the ends of the arc and *y* any point on it. Join chords *xy* and *yz* and bisect them at A and B respectively. Draw A M and B N at right angles to *xy* and *yz* to intersect at C. This C is the required centre of the circle of which *xyz* is the arc.

To make a triangle equal to a given quadrilateral figure.

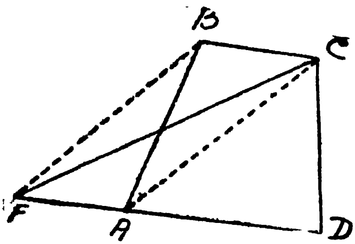
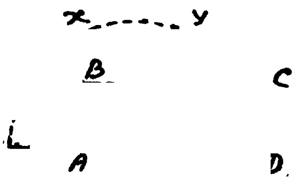


Fig. 23.

Let ABCD be the given quadrilateral. Join AC. Through B draw B F parallel to AC to cut DA produced at F. Join CF. Then CDF is the required triangle which is equivalent to the given four-sided figure ABCD.

To make a square equal to a given rectangle ABCD.



Produce side DA to H making AH equal to AB. Bisect DH. With F as centre and FH as radius describe a semicircle on DH. Produce AB to meet the circle in *x*. On A*x* describe a square A*xyz*. This square will be equal to the given rectangle ABCD.

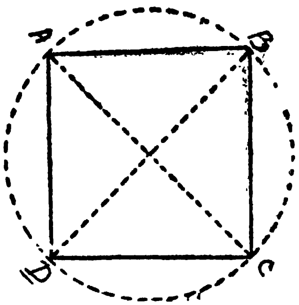


Fig. 25.

To inscribe a Square in a given circle.

Draw a circle ABCD. Draw two diameters AC and DB at right angles to each other. Join ABCD. These will be the sides of the required square.

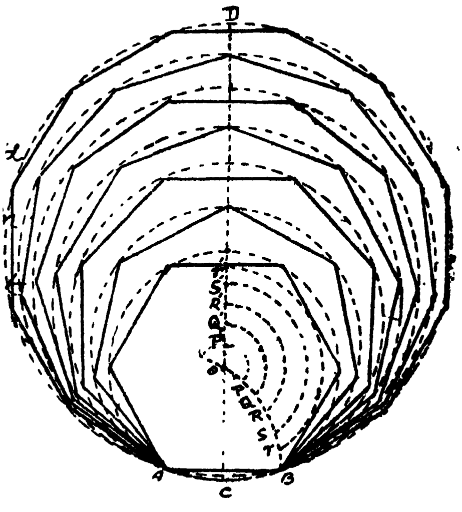


Fig. 26.

A general method of constructing any regular Polygon.

With A as centre and radius AB strike an arc D BO. Divide this arc into six equal parts at points P, Q, R, S, T. With O as centre and radius OP strike an arc to meet the perpendicular CD at P′. Similarly with O as centre and radii OQ, OR, OS, OT describes, arcs to intersect the perpendicular CD in Q′, R′, S′, T′.

If a hexagon is required, with O as centre and radius OA describe a circle and in it lay off lengths AB all round. The figure thus formed is a hexagon. Simliarly to draw a Septagon, Octagon, Nononag, Decagon and so on describe circles with centres at P, Q, R, S, T, etc., and radii PA, QA, RA, SA, TA, etc. Then lay off lengths of AB in each and the polygons produced by joining the points will be Septagon, Octagon, Nonagon and so on. In the same way any required polygon may be easily drawn.

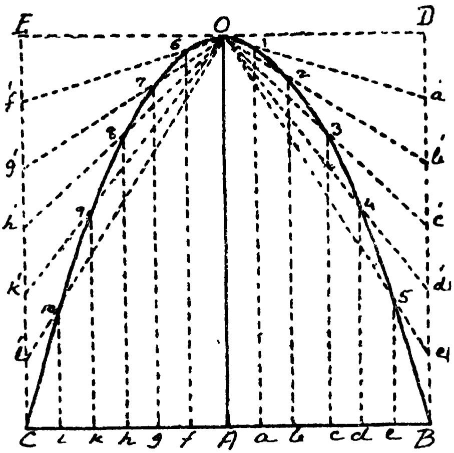


Fig. 27.

To construct a parabola.

The adjoining figure shows a parabola; in it OA is the axis, AB and AC are ordinates; AB being equal to AC. The point O is called the vertex. Through O draw DE perpendicular to OA, and BD and CE parallel to it. Divide BD and BA into the same number of 6 equal parts. Through the vertex O draw *a′ b′ c′ d′ e* to the points of division on BD and through the corresponding points *abcde* on BA draw lines parallel to OA. The points of intersection of these lines (1, 2, 3, 4, 5) are points on the curve, through which it may be traced.

In a similar way draw the other half of the curve through 6, 7, 8, 9, 10. The figure thus formed will be a parabola.

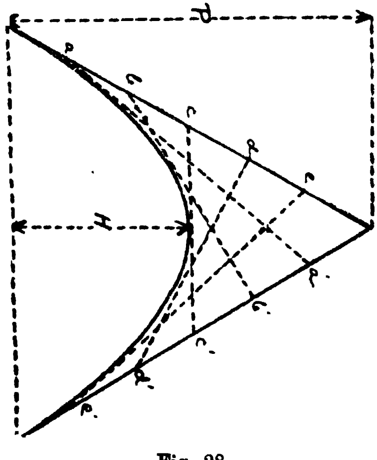
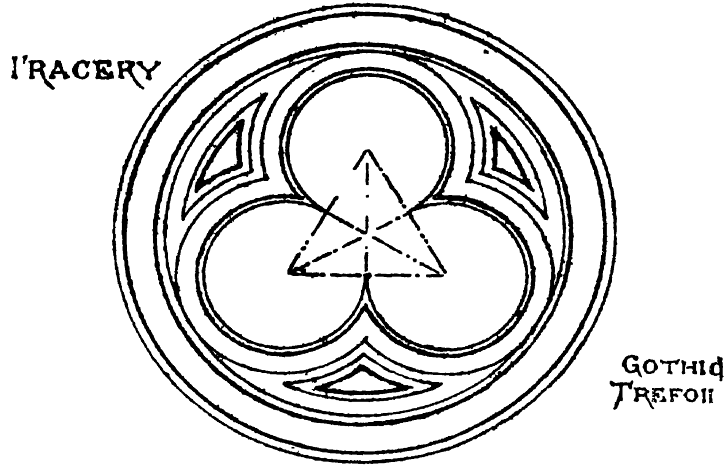


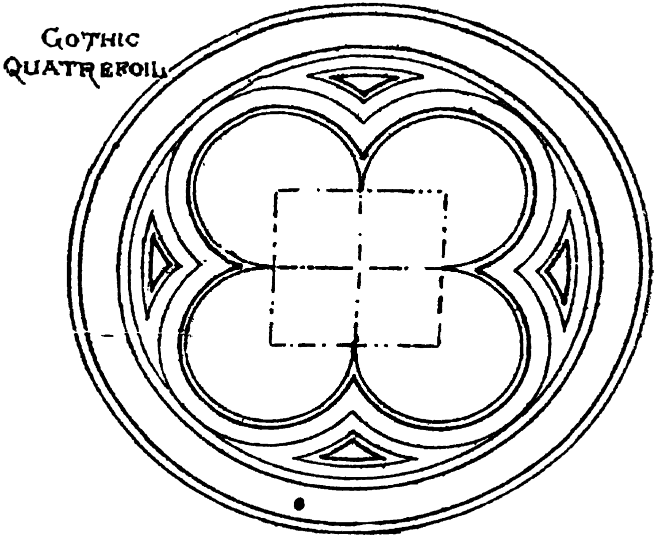
Fig. 28.

Another method of constructing a parabola.

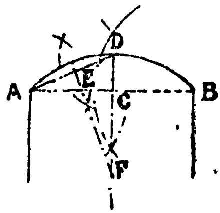
Given the double ordinate and the abscissa H over the double ordinate, construct an isosceles triangle with a perpendicular height equal to 2H or P.

Divide the sides of the triangle into any number of equal parts (say six) at points *a, b, c, d, e* and *a′, b′, c′, d′, e′*. Join *oa′, bb′, cc′, dd′, ee′*. The lines so drawn will be tangents to the required parabola.

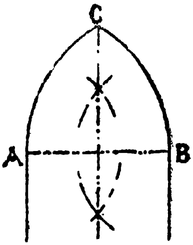

I'RACERY
GOTHIC
TREFOIl


GOTHIC
QUATREFOIL

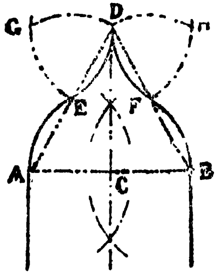
CONSTRUCTION OF ARCHES



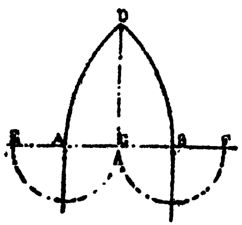
SEGMENTAL



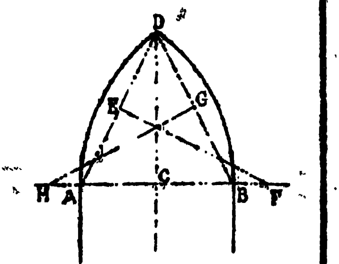
EQUILATERAL



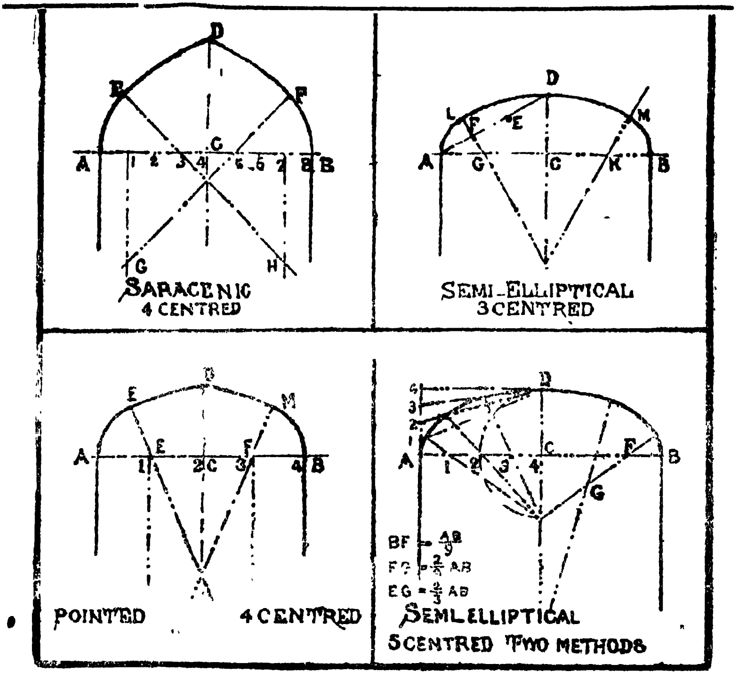
OGEE



LANCET

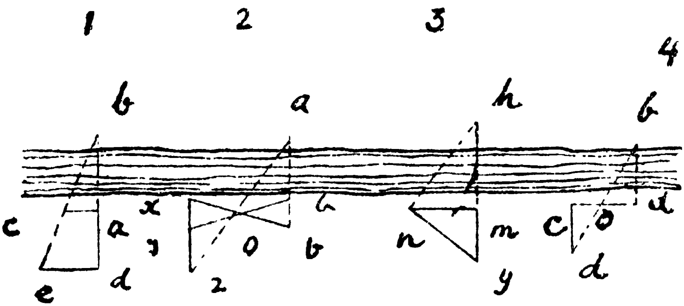


POINTED 2 CENTRED


SARACENIC
4 CENTRED
SEMI-ELLIPTICAL
3CENTRED
POINTED
4 CENTRED
SEMI-ELLIPTICAL
3CENTRED TWO METHODS

SURVEYING.

To find the width of a river or canal of which one end only is accessible.
Diagram.



ab being the distance.

(1) Fix a peg e at right angles to $a\ b$ and then fix e in range with bc so that ed is at right angles to $b\ d$; then by similar triangles

$$a\,c : a\,b :: e\,d : b\,d,$$

$$\frac{ac}{ab} = \frac{ed}{bd} = \frac{ed}{ab + ad}$$

$$\therefore\ ac \times ab + ac \times ad = ab \times ed$$

$$\therefore\ ab\ (ed—ac) = ac \times ad$$

$$ab = \frac{ac \times ad}{e\,d—a\,c}$$

(2) $a\ b$ being the distace. nMake $b\ v$ of any convenient length, in range with $a\ b$. Measure any $v\ o$ and ox equal to it in range. Measure $b\ o$, and $o\ y$ equal to it in range. Place a peg z in range with both $x\ y$ and $a\ o$, then $y\ z$ will be equal to $a\ b$.

(3) $m\ h$, being the distance, place a peg at n and lay off the angle $b\ m\ n = 90°$ at any convenient distance $m\ n$, place a peg at n. Make the angle $h\ n\ y = 90°$ and place a peg at y, in range with $h\ m$. Measure $m\ y$ and $m\ n$ then from principle of similar triangles.

$$m\,y : m\,n :: m\,n : m\,h.$$

$$\therefore\ \frac{m\,y}{m\,n} = \frac{m\,n}{m\,h}\ \therefore\ m\,h = \frac{(mn)^2}{m\,y.}$$

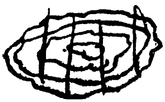
(4) From a, lay off any angle $b\ a\ c$. In the line $a\ c$, at any convenient point c, drive a peg, and from c lay off an angle $a\ c\ d$, equal to the angle $b\ a\ c$. In the line $c\ d$, at any convenient point as d, drive a peg. Then standing at d, and look-

ing at *b*, place a peg *o* in range with *d b* and at the same time in the line *a c*. Measure *a o*, *o c* and *cd* then as before.

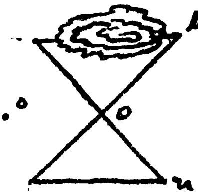
$$o\,c : c\,d :: a\,o : a\,b.$$

$$\frac{o\,c}{c\,d} = \frac{a\,o}{a\,b} \quad \therefore \quad a\,b = \frac{a\,o \times c\,d}{o\,c.}$$

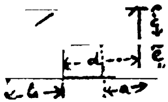
II. To find the distance *a b* of which the ends *a*, *b* are only accessible.



Draw *a m* any distance and bisect at *o* making *a o* = *o n*. Similarly draw *b m*, bisect at *o* making *b o* = *o m*.
then *m n* = *a b*.



III. To find the height of an object without instruments.



(*a*) Measure a distance *d* on a level ground and erect a bamboo at one end of known height. Then stand at such a point that the end of bamboo, your line of sight and the top of the object intersect and measure that distance.

Again erect the bamboo on the other end of the distance *d* and again find a similar point. Measure *a* and *b*; substract *c* from the height of the bamboo; which will give c

$$\text{then } L.\ i.\ e.,\ \text{height required} = \frac{d-c}{b-a} + c + e.$$

(*b*) By means of its shadow.

Plant one end of a straight stick vertical in the ground, and measure its shadow, also measure the length of the shadow of the object. Then as the length of the shadow of the stick is to the length of the stick above ground, so is the length of the shadow of the object to its height.

If the object is inclined, the stick must be equally inclined.

Colours to be Used in Survey Drawings.

Maps—

Water	.. *Indigo.*
Roads	.. *Burnt Sienna.*
Rail roads	.. *Thick black line.*
Dry nallas	.. *Burnt umber.*
Brick houses	.. *Lake.*
Mud houses	.. *Light Indian ink.*
Canals	.. *Thick blue line.*
Rajbahas	.. *Thin do.*

Plans and Sections of Buildings—

Boulders	.. *Light shade burnt umber, with boulders marked in Indian ink.*
Boulder in mortar	.. *Light shade lake, with boulders marked in dark lake.*
Stone-work	*Burnt umber.*
Burnt bricks, laid in mortar	*Lake.*
Burnt bricks, laid in mud	*Light red.*
Unburnt bricks, laid in mud	*Light shade Indian ink.*

Earthware—

Natural	*Burnt sienna.*
Made	*Light shade burnt sienna and Indian ink.*
Iron work	*Indigo and Indian ink, light shade*

Woodwork—

Fir	.. *Yellow ochre.*
Hardwood	.. *Burnt sienna and burnt umber.*

Conventional Signs used in Surveying.

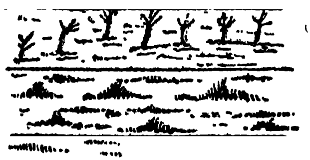
Fit for cultivation uncleared—

Bamboo Jungle ..



Forest, or Tree Jungle

Low, or Bush Jungle



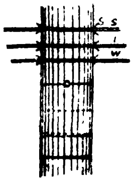
Jhow Jungle

Grass do.

Grazing Ground

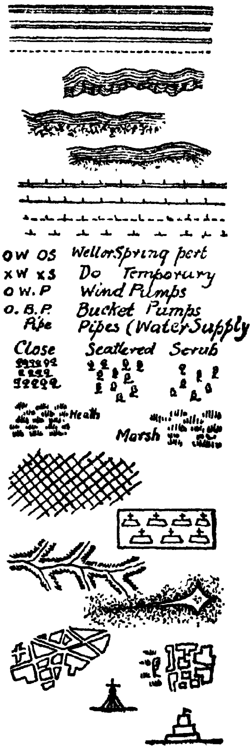


Conventional Signs

Names	Signs
Anchorage	
Boundaries	International Provincial Tribal + District
Boundary Pillars	B P6.
Canals	1st Class (Lock, Regulator) 2nd do Drainage
Churches + Chapels	Simple, with spire, with tower
Mosques + Temples	mosque, temple
Fort	
Mission Stations	Protestant + P.M Roman Catholic + R.C.M
Lake	
Cultivation	or
Lighthouse + Wireless Station	
Mills	A Steam, wind, water
Post office etc.	T telegraph office t telephone do P Post do P
Railways — Double	Tunnel, culvert over, Road
Railways — Single	kana Sta., viaduct, Level crossing
Railways — Light	embankment, under, Road, cutting
Railways — Projected	
Rivers — Large	Falls or Rapids
Rivers — Small perennial	
Rivers — Sometimes dry	
Rivers — Unsurveyed	
Rivers — Nullah Donga etc.	
Ruins	
River Passages — Bridges Stone	 S S, I, W
River Passages — Do Iron	
River Passages — Do Wood	
River Passages — Ferry	
River Passages — Foot Ford	
River Passages — Wagon Ford	
River Passages — River Dam	

Conventional Signs (continued)

Names	Signs
Roads in order of importance	
Sea Coast: Cliffs	
Sea Coast: Flat Roks	
Sea Coast: Sand	
Telegraph or Telephone Lines: Along roads imp	
Telegraph or Telephone Lines: Do. unimportant	
Telegraph or Telephone Lines: Along Tracks	
Telegraph or Telephone Lines: Not along roads	
Wells, Springs etc	
Woods	
Heath, Marsh	
Obstacles	
Cemetry	
Ravines	
Sand Hills	
Town, Village	
Signal Staff	
Masonry Semaphore	



Chaining on Sloping Ground.

The distances required in surveying are horizontal distances. Hence if the ground slopes, this must be corrected in some way.

For shorter steep slopes when great accuracy is not required, the chain is stretched along the slope and reading taken.

For longer slopes or more accurate work, the angle of slope is measured; and the required allowance made.

The following table gives the deductions or additions to be made for 100 ft. length.

The Surveyor should copy this down in his Survey book.

Table of deductions or additions to be made per 100 feet in chaining over sloping ground.

Slope in degrees	Deduc. feet.	Rise in 100 feet hor.	Slope in degrees	Deduc. feet.	Rise in 100 feet hor.	Slope in degrees	Deduc. feet	Rise in 100 feet hor.	Slope in degrees	Deduc. feet	Rise in 100 feet hor.
	·015	1·746		·548	10·51		1·837	19·44	16	3·874	28·57
	·061	3·492		·745	12·28		2·185	21·26	17	4·370	30·57
	·137	5·241		·973	14·05		2·563	23·09	18	4·894	32·43
	·244	6·993		1·231	15·34		2·970	24·93	19	5·448	34·43
	·381	8·749		1·519	17·63		3·407	26·79	20	6·031	36·40

CHAIN SURVEY.

In chain survey we have no instrument for measuring the angles, hence the lines should be arranged in such manner that they can be plotted from the lengths alone. Now a triangle is the only figure which can be so plotted, hence the first essential is that there should be one or more main triangles as big as can be obtained on the ground.

General conditions : to be kept in view in arranging the lines are :—

(1) Arrange one or more main triangles.

(2) All the lines must be capable of being plotted from their measured lengths alon, by intersecting arcs.

(3) If any lines have to be produced on paper after being plotted, the part produced should be very short in comparison with the part already laid down.

(4) All triangles should be what is called "Well conditioned" (*i. e.*, Equilateral in form).

(5) The lines should be as few as convenient.

(6) In arranging lines which have to pass through hedges ; avoid crossing the hedges oftener than necessary.

(7) There must be a sufficient number of tie or subsidiary lines to form a check on the accuracy of every part of the chaining when plotted.

Chains.—(1) 100 ft. chain or Engineer's chain.

(2) Gunter's chain of 66 ft. length.

In Gunter's chain the length of one link is 0·66 ft.

Setting out a Right Angle with a Chain.

Construct a right angle triangle on the ground in following ratios :—

3 : 4 : 5	$1 : 1 : \sqrt{2}$
5 : 12 : 13	$1 : \sqrt{3} : 2$

Prismatic Compass Survey.

Centering :—The compass for all but the roughest surveying purposes, is usually mounted on a tripod, so that it can be centered over the station like a theodolite. It is less sensitive hence it need only be approx. centered.

Levelling.—The levelling is usually done by eye, by means of a ball, and socket joint in the head of the tripod. A clamp is provided to fix the joint when levelled.

Field Book.—The compass is set up at alternate stations only, the forward bearing being read for one line, and the back bearing for the one before. For plotting the line whose back bearing is measured, we use the measured bearing $\pm$ 180.

For the best work, we set up at each station, and the bearing of each line is read both backwards and forwards.

The field book is then ruled as follows :—

Line.		Forward bearing.	Back bearing.	Mean.	Remarks.
AB	..	76°—12′	256°—18′	76°—15′	BX=185° ·48′
BC	..	93°—18′	273°—18′	93°—18′	
CD	..	167°—42′	345°—12′	167°—42′	
DE	..	178°—30′	1°—6′	181°—6′	
EF	..	193°—18′	13°—24′	193°—21′	

At A we read the forward bearing of A B and at B we read the back bearing of A B and the forward bearing of B C and so on. At B a line BX branches off, it is supposed, and its bearing is entered in the remarks column.

To Determine A True East and West.

Set up a vertical rod (any size) on a flat floor. Describe a circle round the base about twice the height of the rod. Sometimes in the forenoon mark the point where the shadow of the rod just touches the circle and repeat this in the afternoon on the other side of the circle. Mark this point also. A line through these points will be true East and West. The method is useful in setting sun-dials, setting out buildings, etc.

Method of Determining the Direction of True North.

(1) 1*st Method.*—By means of magnetic compass the variation of which from True North may be seen by reference to the Admirality Chart.

(2) By ascertaining true " Local time " and taking the direction of a shadow cast by a vertical rod at mid-day.

(3) By means of a vertical pole and its shadow as follows :—

Select a convenient station, A, upon the main line, where the ground is smooth and level and plant a pole there firmly and truly vertical, follow the above construction (as for True East and West). Bisect the distance between the two points and a line joining this point through the station will be in the direction of the True North.

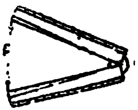


Table of Angles corresponding to openings of a Two-Foot Rule.

If the inner edges of a common foot rule be open to the extent shown in the column of inches they will be inclined to each other at the angles shown in the columns of angles. No great accuracy is to be expected as the opening of ⅛th inch corresponds to 1° up to 105° and from 1½ degrees to 12° beyond 105°, *i.e.*, upto 180°.

D=Degrees

M=Minutes

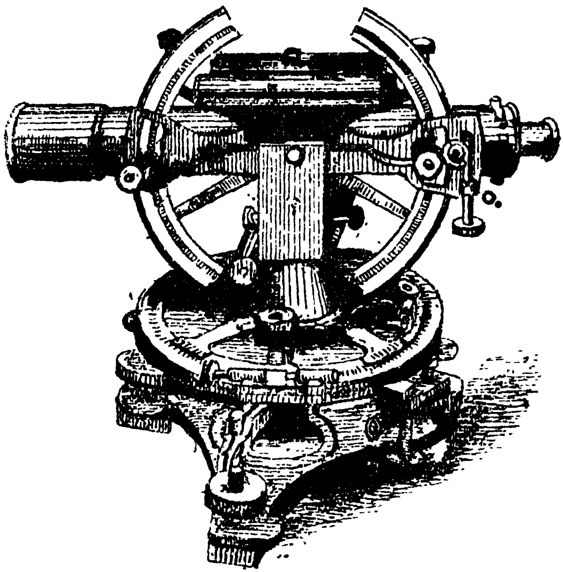
Ins.	Angle.		Ins.	Angle.		Ins.	Angle.		Ins.	Angle.		Ins.	Angle.		Ins.	Angle.	
	D.	M.		D.	M.		D.	M.		D.	M.		D.	M.		D.	M.
¼	1	12	1¾	8	22	3¼	15	34	4¾	22	50	6¼	30	11	7¾	37	41
	1	48		8	58		16	10		23	27		30	49		38	19
½	2	24	2	9	34	½	16	46	5	24	3	½	31	26	8	38	57
	3	00		10	10		17	22		24	39		32	6		39	35
¾	3	36	¼	10	46	¾	17	59	¼	25	16	¾	32	40	¼	40	13
	4	11		11	22		18	35		25	53		33	17		40	51
1	4	47	½	11	58		19	12	½	26	30	7	33	54	½	41	20
	5	23		12	34	4	19	48		27	7		34	33		42	7
¼	5	58	¾	13	10	¼	20	24	¾	27	44	¼	35	10	¾	42	46
	6	34		13	46		21	00		28	21		35	47		43	24
½	7	10	3	14	22	½	21	37	6	28	58	½	36	25	9	44	3
	7	46		14	50		22	13		29	35		37	3		44	42

Table of Angles corresponding to openings of a Two-Foot Rule.—concluded.

Ins.	Angle. D.	Angle. M.	Ins.	Angle. D.	Angle. M.	Ins.	Angle. D.	Angle. M.	Ins.	Angle. D.	Angle. M.	Ins.	Angle. D.	Angle. M.	Ins.	Angle. D.	Angle. M.
9¼	45	21	11¾	58	38	14¼	72	51	16¾	88	31	19¼	106	39	21¾	129	59
	45	59		59	19		73	36		89	21		107	40		131	25
½	46	38	12	60	00	½	74	21	17	90	12	½	108	41	22	132	53
	47	17		60	41		75	6		91	3		109	43		134	24
¾	47	56	¼	61	23	¾	75	51	¼	91	54	¾	110	46	¼	135	58
	48	35		62	5		76	36		92	46		111	49		137	35
10	49	15	½	62	47	15	77	22	½	93	38	20	112	53	½	139	16
	49	54		63	28		78	8		94	31		113	58		141	1
¼	50	34	¾	64	11	¼	78	54	¾	95	24	¼	115	5	¾	142	51
	51	13		61	53		79	40		96	17		116	12		144	46
½	51	53	13	65	35	½	80	27	18	97	11	½	117	20	23	146	48
	52	33		66	18		81	14		98	5		118	30		148	58
¾	53	13	¼	67	1	¾	82	2	¼	99	00	¾	119	40	¼	151	17
	53	53		67	44		82	49		90	55		120	52		153	48
11	54	34	½	68	28	16	83	37	½	100	51	21	122	6	½	156	34
	55	14		69	12		84	26		101	48		123	20		159	43
¼	55	55	¾	69	55	¼	85	14	¾	102	45	¼	124	36	¾	163	27
	56	35		70	38		86	3		103	43		125	54		168	18
½	57	16	14	71	22	½	86	52	19	104	41	½	127	14	24	180	00
	57	57		72	6		86	41		105	40		128	35		..	..

THEODOLITE

Everest's Double Arc Theodolite



The theodolite is commonly made in either of the following three forms, *viz.*, the " Everest's, the " Y " pattern or the more modern " Transit."

It is not considered necessary to give description of all the parts, but the method of adjustment has been given below :—

There are four adjustments which will be described in the proper order.

(1) The plate levels should be perpendicular to the vertical axis.

To test this, set one bubble parallel to any two plate screws (if there are only three of the latter) or to two opposite screws if there are four. Level both levels with the plate screws, the outer axis being firmly clamped.

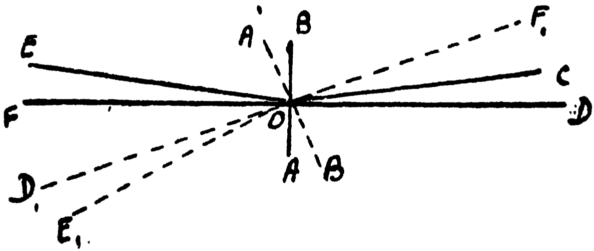
Now turn through 180°, unclamping the inner axis or upper plate for this.

If either bubble moves. correct half the amount with the screws which support that level, and the other half with the plate screws to which it is parallel. Repeat till perfect.

When the bubbles both remain central in all positions, unclamp the outer axis and turn the instrument round it. If the bubbles move, the axis are not parallel and this defect cannot be remedied except by the makers.

(2) The line of collimation should be perpendicular to the trunnion or horizontal axis.

To test it, level up carefully and look at any well marked point c both horizontal plates being clamped.



Let A B be the plan of the trunnion axis and F O D the true perpendicular to it, while O C is the line of collimation.

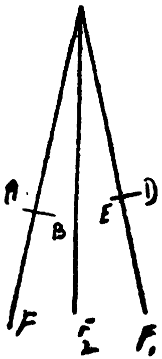
Now transit the telescope (*i. e.*, turn it over vertically round the horizontal axis) and the line of collimation will now be along O E. Mark the point E in line with the hairs.

Then turn the theodolite round horizontally to look back to C. If D O C= FOE=α, it is clear that the angle turned through will be 180—2α. The trunnion axis will take up the position A_1 B_1 and the perpendicular to it will be D_1 O F_1 O C is the line of collimation as before.

Lastly transit the telescope again, this time round A_1 B_1. The direction of the line of collimation will now be O E_1. If the cross hairs or wires come back exactly on to the old point E, the adjustment is perfect. But if not, mark the new point E_1. Then mark D_1 so that E_1 $D_1=\frac{1}{4}\times E_1$ E, and bring the cross hairs to coincide with the mark D_1 by working the diaphragm screws one on each side.

The adjustment may also be tested as follows :—Direct on to any point C, with all motions clamped and the telescope horizontal, and read both verniers on the horizontal circle. Then reverse face, bisect the same point again and again read both verniers. The mean reading should be the same with each face. If not, half the difference gives the collimation error. To correct it, set the verniers to the mean reading and bisect the mark by the diaphragm screws.

(3) The horizontal or trunnion axis should be perpendicular to the vertical axis.



If this adjustment is perfect then when the instrument is carefully levelled the line of collimation will describe a true vertical plane when the telescope is revolved vertically. But if not the plane will be inclined.

To test it, level up very carefully, and direct the instrument to any well marked fixed point C, preferably at an altitude of not less than 45° with both horizontal movements clamped. Then, if the adjustment be faulty, the trunnion axis will be inclined, as shown at A B, and the line of collimation will describe the plane C F.

Turn the telescope down and mark the point F in line with the hairs, as low down as possibly, and preferably at such a distance that little or no alteration of focus is necessary. Now reverse face, and direct back to C. The slope of the trunnion axis will be reversed as shown at D E, and the plane described will now be CF_1. Mark the point F_1 as before. If F and F_1 coincide, the adjustment is perfect. If not mark F_2 midway between them. It will be found that one end of the trunnion axis can be raised or lowered by one or more capstan headed screws there.

Adjust the moveable end a little at a time and keep on looking at C and F_2 until the cross hairs concide.

(4) The line of collimation should be parallel to the spirit level if the latter be on the telescope.

If the upper spirit level is on the T piece, the line of collimation should be parallel to it when the vertical vernier reads zero.

To test this adjustment, level up very carefully as for vertical angle and then read the vertical angle to any well marked fixed point. Suppose that when the levelling was complete and the vernier set to the horizontal reading, the line of collimation was pointing slightly upwards instead of being horizontal. Then clearly when we raise it to look at the object, the reading on the vernier will be too small.

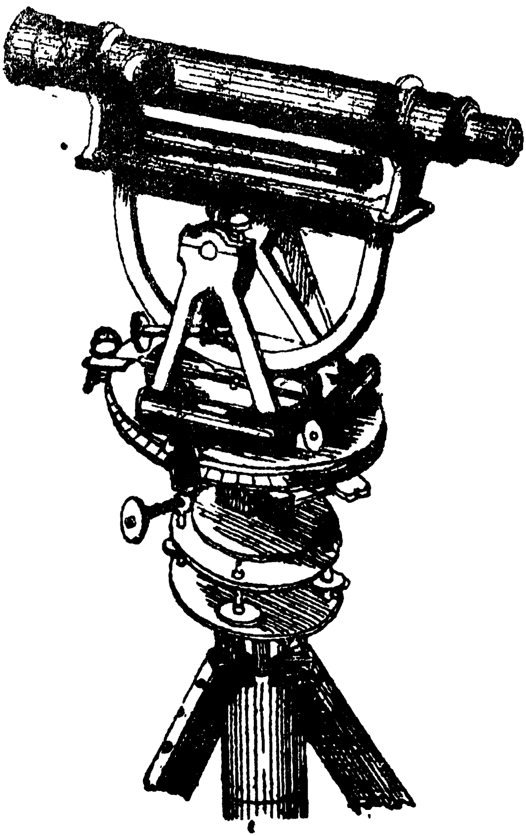
Now reverse face and read the angle to the same object again. The telescope being now upside down, the line of collimation which was before pointing upwards, will now point downwards when the vernier reads zero.
Hence the observed vertical angle to the object will now be too great.

The mean of the two readings will give the correct angle of elevation.

To correct the error we may adjust either the line of collimation or the spirit level.

For this final adjustment that face must be used which will cause the level to be right way up.

Y—Theodolite.



TRAVERSE SURVEYING.

Traverses may be (1), closed (2) open.

(1) A closed traverse is one in which a complete circuit is made.

(2) An open traverse is one when a traverse does not form a complete circuit.

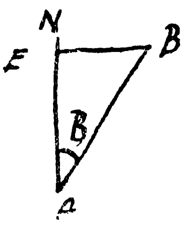
The directions of the Survey lines are fixed by angular measurements.

The ***Bearing*** of a line is the angle it makes with some standard direction. The ***Magnetic Bearing*** of a line is its inclination from the north end of the magnetic meridian measured clockwise.

Whole Circle Bearings :—The bearing of each line is measured clockwise from the standard direction to that of the line right round the circle.

Reduced Bearings :—The bearings are measured clockwise, or ante clockwise from which ever of those directions is the nearer.

Calculation of Bearings :—To the known whole circle bearing of any line add the included angle between that line and the next, if the sum be greater than 180°, subtract 180° but if the sum be less than 180°, add 180°. The result will be the whole circle bearing of next line.



Difference of Latitude and Departure :—Now suppose A N is the standard direction, and that A B is a line at a bearing B. In passing from A to B we go North, *i. e.*, in the direction of A N by an amount A E and east by the amount E B. The distances A E and E B are called the difference of Latitude and the Departure respectively of that line.

Difference of Latitude =Length of line×Cosine of R.B.

Departure=Length of line× sine of R. B. (R. B.= Reduced Bearing).

A difference of latitude if North is called Northing, if South a Southing, similarly if East Eastings and if West Westings.

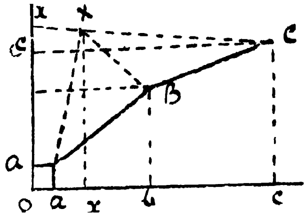
Checks on Closed Traverse :—

(1) The sum of the included angles should be equal to twice as many right angles as the figures has sides plus or minus 360 according to whether exterior or interior angles are measured.

(2) The sum of the Northings must be equal to the sum of Southings and similarly the sums must be equal for Eastings and Westings.

Method of checking an open traverse :—

Let A B C be a portion of traverse plotted with reference of two axis.



An auxiliary station X is fixed outside the traverse or a number of such stations may be fixed if necessary. Bearings are taken from these stations to the various stations of the traverse. The rectangular co-ordinates of X are calculated by using the co-ordinates of A and B, the bearings and lengths of A X and B X being known. The co-ordinates of X are next calculated by using the co-ordinates of B and C, the bearings and lengths of B X and C X being known. The two results should coincide.

Trigonometrical Surveying.

Trigonometrical survey is one in which the three sides of a triangle are computed from the length of a single Base line and from the three angles of each triangle measured with a theodolite and calculated by Trigonometry. There are 3 types of systems. (1) A series of approximate equal triangles. (2) A series of central polygons. (3) A series of quadrilaterals with both diagonals drawn.

Sub-division of Field work :—The process of carrying triangulation scheme may be divided as follows :—(1) Reconnaissance of preliminary work. (2) Base line measurement. (3) The measurement of the angles. (4) The Astronomical observation.

Trigonometrical Levelling.

Finding the difference in elevation of two points by means of the horizontal distance between them and the vertical angle is called Trigonometrical levelling.

Level.

The Y Level :—The telescope instead of being firmly fixed to its supporting bars is carried into two Y shaped bearings.

The term adjustments and method of use are the same for a Y as for a dumpy level.

Permanent adjustments :—They are 3 in number.

(1) Make the line of collimation coincident with or parallel to the axis of rotation of the telescope in the Y's.

Turn the telescope through 180° in its Y's after having sighted the horizontal wire on a well defined object, when if the wire has moved from the object it must be brought back, half by the foot-screws and half by the diaphragm screws. Repeat till perfect.

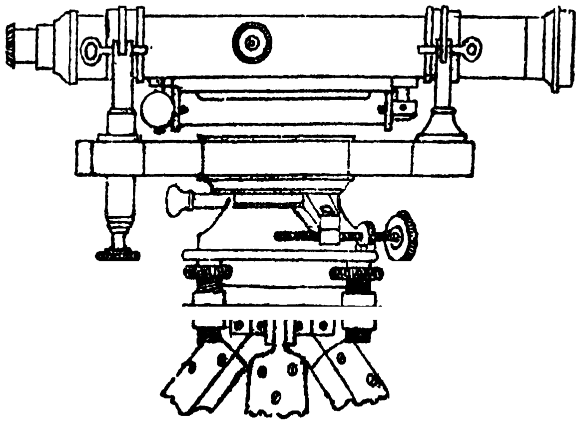
(2) To make the telescope level parallel to the axis of rotation in its Y's and therefore parallel to the line of collimation.

Bring the bubble to the centre of its run, by means of foot screws. Reverse the telescope in its Y's, when if the bubble does not remain in the centre of its run, correct half the displacement by the foot screws and half by the screw at one end of the level. Now rotate the telescope slightly in its Y's and if the bubble does not remain steady, adjust by means of nuts provided for this purpose which give lateral motion to one end of the level.

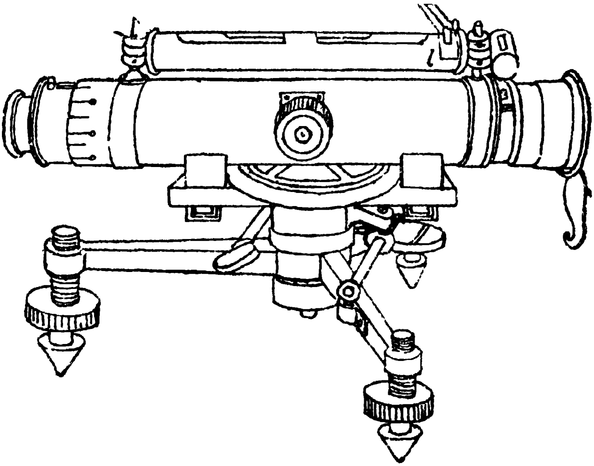
(3) To make the vertical axis of rotation truly vertical and to put the line of collimation and telescope level at right angles to it.

Turn the telescope till it is over two foot screws and bring the bubble to the centre of its run by them. Then turn the telescope through 180°. If the bubble is not still in the centre of its run, correct half the displacement by the foot screw and half by the thumb screw fixed to one of the Y supports. Now turn the telescope through 90° and correct with a third foot screw (or other pair of foot screws). Repeat adjustment till the bubble remains in the centre of its run during a complete revolution of the telescope.

LEVEL



LEVEL.



DUMPY LEVEL.

Temporary Adjustments.

(1) Set up the level firmly with legs firmly planted.

(2) Level the telescope by means of plate screws.

(3) Elliminate parallax, that is to say that the cross hair should not move up and down when the eye is moved up and down.

It can be tested by moving the eye about after focussing both the hairs and the object. If the hairs appear to move with reference to the image, work the focussing screw so as to adjust the draw tube a little at a time and keep on until there is no further movement.

Permanent Adjustments.

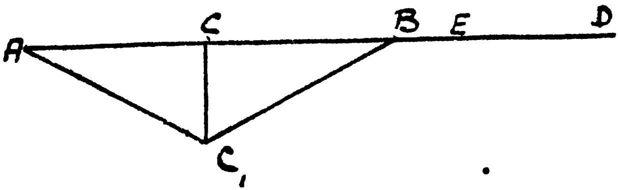
(*a*) The line of collimation should be parallel to the axis of the draw tube so that its direction does not alter with the focus.

(*b*) The line of collimation and the spirit level should be parallel to one another.

(*c*) The vertical axis of rotation should be perpendicular to the spirit level

(*a*) The adjustment (*a*) is usually neglected and assumed as correct.

(*b*) To test, choose two firm points A and B on a fairly level ground say 150 to 200 feet apart, and set up the level, if possible, at C exactly midway between them, or at any point C_1 such that $A C_1 = B C_1$



Level up, and read the staff at A and B, correcting the level for each reading if necessary. The difference between the readings will give the correct rise or fall, where there is an error in the line of collimation or not, because the distances are equalized.

Now set up at D, in the line A B produced, so that B D is 75 to 100 feet long, and preferably exactly half of A B. Level up, and read again at A and B. If the difference is the same as before the adjustment is correct. But if the line of collimation, is not parallel to the spirit level, the reading at A will have a bigger error than that at B, in consequence of the greater distance. Hence, the difference in readings will not be the same as before. This difference indicates an error and we may correct it by altering either the line of collimation or the spirit level. If the line of collimation is at fault, the adjustment should be made with the diaphragm screws.

(*c*) To test this, level up, and turn the level through 180°. If the bubble moves, correct half the error by plate screws and half with the opposing screws.

Next turn through 90° and level with foot screws only. Then repeat till the bubble remains nearly central in all positions.

There are two methods generally employed in levelling.

(1) Rise and fall method.

(2) Height of instrument method.

Checking Arithmetic.

The difference between the sums of all backsights and foresights should be the same as the difference between the first and the last reduced levels.

Comparison of Level Books.

The rise and fall method of keeping the level book involves more arithmetic than the height of instrument method, but affords a more complete check on arithmetic.

CONTOURING.

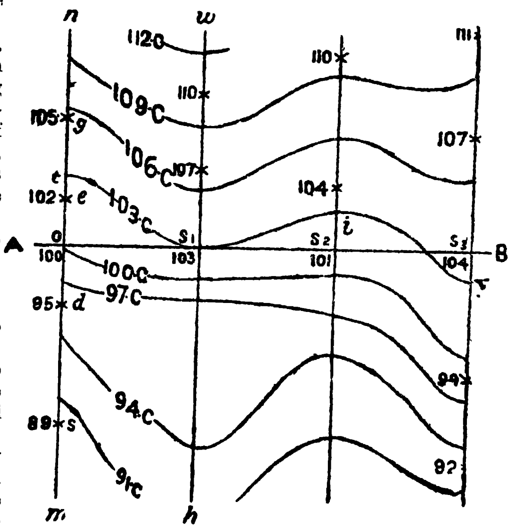
A contour line is a line drawn on the plan, so as to pass through all points which have the same reduced level. If two such contours are drawn all points on the one will be the same vertical distance above or below those points which lie on the second contour.

This vertical distance is called the vertical interval between contours, and varies from 1 foot to about 10 feet in large scale plans for buildings and from 10 feet to 100 feet or more in small scale maps.

The method generally adopted for finding the contours in engineering plans, is to cover the ground with a series of " spot levels " one or more lines are arranged out on the ground in known directions, and cross sections are taken along lines either at right angles to these or making known angles with them. The levels are taken along these lines and booked, thus giving the reduced levels of a number of spots along these cross sections. Extra points are taken between cross sections if there is any irregularity in the ground. The contours are then interpolated on the plan.

Method of Plotting.

Let A B be the centre line of a road and the con touring starts from O. S_1, S_2, S_3, are the station on it, the reduced levels being 100, 103, 101 and 104 respectively. Now at each of these stations O, S_1, S_2, etc., draw perpendiculars mn, hw, etc., and suppose O e, o g, are the perpendiculars on mn at O and the reduced levels are 102 and 105 and Od, Sd are the perpendiculars b e l o w O whose reduced levels are 95, 89. Similarly on h w at the stations, S_1, there are perpendiculars whose reduced levels are 107 and 101. Go on taking reduc ed levels in the same way on other stations both above and below the stations as shown in the sketch below.



Let the vertical interval be 3 feet. The contour line will be from one foot above the station e. Mark this as t. The reduced level at S_1 is 103 and this point will remain the same and so on and complete as shown in the sketch when all the points t s, i y are fixed, draw a curve through these and this will give a contour.

LEVELLING WITH BAROMETER AND THERMOMETER.

Rule.—Take readings of the barometer and thermometer in the shade at both stations, add together the two readings of the barometer and divide by 2, and call it b. Do the same with two readings of thermometer and call it t. Subtract the least reading of barometer from the greatest and call the difference d. Then multiply together this difference d and the number from the table opposite t, and by 30. Divide the product by b.

$$\text{Diff. of height in ft.} = \frac{K \times d \times 30}{b}$$

EXAMPLE.—Reading of a barometer at lower station is 26·64 inches and at the the upper station 20·82 inches. Thermometer reads 70° at lower station and 400 at upper station. What is the difference of height of the two stations.

Barometer.	Thermometer.	Difference.
26·64	70	
20·82	40	26·64
29|47·46	2|110	20·82
23·73=b	55=t	5·82=d.

and K for 55 in the table below is 917·2

$$\therefore \text{ Height required } \frac{30 \times 5{\cdot}82 \times 917{\cdot}2}{23{\cdot}73} = 6748{\cdot}5 \text{ ft.}$$

Mean of Ther= *t*.	K	Mean of Ther= *t*.	K	Mean of Ther= *t*.	K	Mean of Ther= *t*.	K
0°	801·1						
5°	811·7	35°	874·9	65°	938·2	95°	1001·6
10°	822·2	40°	885·4	70°	948·8	100°	1012·1
15°	832·8	45°	896·0	75°	959·3	105°	1022·7
20°	843·3	50°	906·6	80°	969·9	110°	1033·2
25°	853·9	55°	917·2	85°	980·4	115°	1043·8
30°	864·4	60°	927·7	90°	991·0	120°	1054·3

Rule for finding the value of K for any value of t

$$K = t \times 2{\cdot}11 + 801{\cdot}1$$

Let t =72 then K=72×2·11+801·2=953·0

In case great accuracy is required, apply also the correction for latitude given in the table below. If two places are at different latitudes, apply their mean. No correction is required for latitude 45°. Divide the height found by above method by the number on the table below. Add the quotient to the altitude if the latitude is less than 45° and subtract if the altitude is more than 45°.

Example.—In the above example the latitude of point $A=31\frac{3}{4}°$ and of $B=32\frac{1}{4}°$, find the correct height between A and B.

$$\text{Average latitude} = \frac{31\frac{3}{4}+32\frac{1}{4}}{2} = 32°$$

The table below gives 804 for 320.

$$\text{Correct height} = \frac{6748{\cdot}5}{804} + 6748{\cdot}5 = {\cdot}6756{\cdot}9 \text{ ft.}$$

Table of Corrections for Latitude.

Lat.	Divider.	Lat.	Divider.	Lat.	Divider.	Lat.	Divider.	Lat.	Divider
0	352	16	416	32	804	46	10101	62	630
2	354	18	436	34	941	48	3367	64	572
4	356	20	460	36	140	50	2028	66	527
6	360	22	490	38	158	52	1458	68	490
8	367	24	527	..	..	..	1140	70	460
10	375	26	572	40	2028	54	941	72	436
12	387	28	630	42	3367	56	804	74	416
14	399	30	705	44	10101	58	705	76	399

Levelling by Thermometer.

t =temperature of boiling water at any station in F° deducted from 212.

H=Height of the station above the sea level in feet$=520°t+t^2$.

This result is also subject to correction by multiplying with K which vary in the proportion of ·0011 per degree Fahr. approx.

Hydrographic Surveying.

Hydrographic Surveying is the term applied to the process used in surveying any body of water to determine its topography at the bottom. The fieldwork is usually done by first establishing certain points on shore by triangulation or traverse to which the Hydrographic Survey is referred and then measuring (usually from a boat) the depth of the water at various points and determining the position of these points. Besides ordinary transit and outfit a sounding pole or head line and a boat with necessary equipment are required. The head line consists of long chain or hemp rope at the end of which a lead weight is attached. Where there is not much current, a 6 to 10 lbs. weight will suffice for a depth upto 40 feet.

Plane Table Surveying.

The plane table is a portable table by means of which points are located by graphical methods directly on the map. It is a flat drawing board varying in size from 16″×12″ to 30″×24″ and about one inch thick, supported on a tripod with a device for levelling and clamping the board. The table should be provided with water-proof cover.

Locating Points by Intersection.—Select a base *a b* representing to some scale, the measured base A B. The table is set so that *a* on the map is vertically above A on the ground and the table is levelled, then one edge of the alidade is placed along the base line *a b* drawn on the map, the table is then turned in azimuth until the telescope sights the signal B and the horizontal motion clamped. The table is now said to be oriented. The alidade is then placed so that the straight edge passes through *a*, the telescope is sighted to some signal *c* and an indefinite line drawn towards *c*. Remove table to B (*b* being set vertically over B) and the process is repeated, the point *c* is located on an indefinite line through *b*, hence it lies at the intersection of these two lines *a c* and *b c*. The triangle *a b c* is similar to triangle A B C. In similar manner any number of points may be located. The details are then sketched on the map.

Locating Points by Resection.—It sometimes happens that it is desired to locate a plane table station from a base, only one end of which can be occupied with the table. In such a case we proceed as follows:—Let A and B represent the points on the ground at the end of the base line, C is the signal which is to be located, and *a b* represents a base line plotted on the plane table sheet. Set up at A, the end of the base which is accessible and orient the table by sighting B with the alidade along *a b*. Then centering the alidade on a, draw an indefinite line towards C. This line should be drawn the full length of the alidade. The table is then taken to C and oriented by means of indefinite line just drawn. Since the position of C on the indefinite line is not known it is necessary to estimate its position on the map and to use this point in placing the table over the point C. If alidade is now centered on *b* and sighted towards B a resection line may be drawn and the line will cut the first indefinite line, thus locating the point *c* desired.

The Three Point Problem.—The two graphical solutions of the problem are known as—

(1) Triangle of error method.
(2) Inscribed quadrilateral method.

Photographic Surveying.

Surveying by photography is one of the most rapid methods of locating topographic details though not so accurate as plane table. To locate a point on a map it is necessary that the point should appear on two photographs taken from two different camera stations, and in addition the following data must be known, the position of two camera stations, the direction in which the camera was pointed in each case and the focal length of the lense.

The camera for taking the views should possess the following qualities:—

(1) A good lense with an aperture of 45°.

(2) A firmly constructed body to take flat glass plates.

(3) Levelling screws and levels to set the optical axis truly horizontal and the picture plane and vertical rotating axis truly vertical.

(4) Points on a hair stretched, to mark on the negative the trace of the horizontal plane, and also the principal plane of the perspective view.

(5) Some kind of sighting arrangement with which to direct the optical axis of the lens on objects.

(6) The camera should be mounted in vertical rotating axis and have a graduated horizontal limb, on which to read the angle through which the instrument is rotated.

(7) Clamps, verniers, microscopes and tangent screws, etc., as for a theodolite.

The horizonial direction of any point in the picture is given by the angle it makes with the principal line.

$$\text{Tangent horizontal angle} = \frac{\text{Distance from principal line.}}{\text{Focal length.}}$$

Tacheometric Surveying.

Theodolites furnished with stadia diaphragms are known as Tacheometers.

Method of Procedure.—The instrument having been set up, and its height measured, the staff holders are sent in succession to all the points to be surveyed, their movements being directed by signals. Each point is given a number which is entered in the field book and on a sketch plan. The telescope is directed to the staff at each successive position and the readings noted in the proper columns. The horizontal and vertical angles are read and entered. Three dimensions are then obtained for each point and it can then be fixed by means of co-ordinates and the corresponding altitudes are calculated.

The Field Book.—The field book should be ruled with 15 columns: (1) Instrument station, (2) Staff station, (3) Height of instrument, (4) Bearings, (5) Vertical angles, (6) Stadia readings, (7) Length of Ray, (8) Horizontal distance, (9) Vertical height, (10) Axial Readings, (11) Rise, (12) Fall, (13) and (14) Reduced Level, (*a*) Instrument station, (*b*) Staff station, (15) Remarks.

The main differences between a Tacheometer and a theodolite are the following:—

(1) The presence of a third (anallatic) lens, in a third tube, lying just behind the diaphragm. This tube, and consequently the lens, can be racked backwards and forwards within narrow limits, and provides an additional permanent adjustment. This feature distinguishes the Porro—telescope, the invention of the famous Italian Scientist. There is an advantage of additional lens to cut off light, and condense moisture, but its advantages counterbalance such an objection; in the tropics indeed a cutting off of light is a disadvanatge only in dense forest. The telescope being longer, can be transited at one end only.

(2) The insertion of two additional hairs (horizontal) which intercept a length of thestaff which bears a ratio (almost universely 1 in 100) to the distance from the staff to the plumb-bob of the instrument. If the anallatic lens were not fitted, this exact ratio would not apply, but a constant length will have to be added.

Use of the Instrument.

The instrument is essentially designed for obtaining horizontal distances and reduced levels of a number of points, within a radius of 800 feet of any station where it is set up, on rough ground without the use of a chain or tape.

For Railway work it is used to make a contoured plan from which a paper line may be estimated or as a guide to location

The information of this contoured plan is taken from the record of the instrument which gives bearings, distances and reduced levels of points along a traverse and of a number of others on both sides.

The instrument is generally used with four staves, two on the traverse and one to right and one to left. The staves should be specially graduated, as for distances above 500 feet it is difficult to reod. They should be fitted with a Plumb-bob.

Practical Hints on Workiny the Tacheometer.

In recording the bearings with a Tacheometer, it is the universal custom to work with an oriented instrument. By this means the bearings are read to minutes on the limb of the theodolite and the compass is a check on readings at any point. This is done as follows. At whatever point the traverse is begun, the levelled instrument has its upper plate clamped to 360° or 0°, then the instrument is moved on its lower plate till the box or prismatic compass reads north, with the object glass pointing north the lower plate is then clamped, the upper released and turned on to the first line and its bearing read directly on the limb of the theodolite in minutes. A still more accurate method is by obtaining a true bearing of the first line from a solar azimuth, then,with the upper plate clamped to that bearing, sight on to the first line by the lower plate; on releasing the upper plate the true bearing of any other line can be read on the theodolite to minutes.

When the instrument is carried to the 2nd point and levelled:—With the upper plate clamped to the bearing from (1) to (2) invert the telescope and sight on to the 1st point, clamp the lower plate, and release the upper. Now. on inverting the telescope and turning to any other point, its bearing is again read on the limb of theodolite.

Curve Ranging.

Curves are defined by the length of their radii, in chains of 66 ft. (100 links) or 100 ft.

In much recent practice they are termed 1° curve, 2° curves, etc., the number of degrees indicating the angle at the centre subtended by a chord of 100 ft.

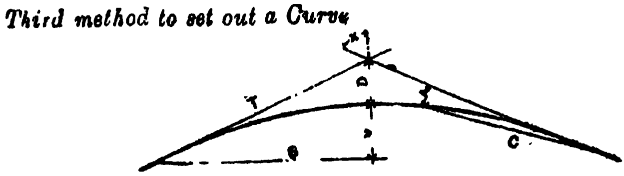
For instance, a circle described with a radius of 5.730 ft. has a circumference of approx. 36,000 ft., and as there are 360 degrees in a circle, every 100 ft. of an arc or chord subtends an angle at the centre of 1°. This is 1° curve.

The length of the chord and arc are always assumed to be equal.

AB is called tangential angle.

$$\angle = 1719 \times \frac{\text{chord}}{\text{radius}} \text{ approx.}$$

Third Method to set out a Curve.



R = Radius of curve .. ..

T = Length of tangent .. ..

x = Half angle of intersection .. ..

D = Distance of centre of curve from intersection .. ..

C = Any chord .. ..

A = Tangential angle of C in minutes .. .. ..

$R = \frac{1719C}{A}$ .. ..

R = T (tan. x) .. ..

T = R (co-tang x) .. ..

D = R (co-secant. x) .. ..

$A = \frac{1719\ C}{R}$ .. ..

S = R (co-sine. x) .. ..

V = R (co-versine. x) .. ..

Number of chords in the curve $= \frac{5400 - x}{A}$

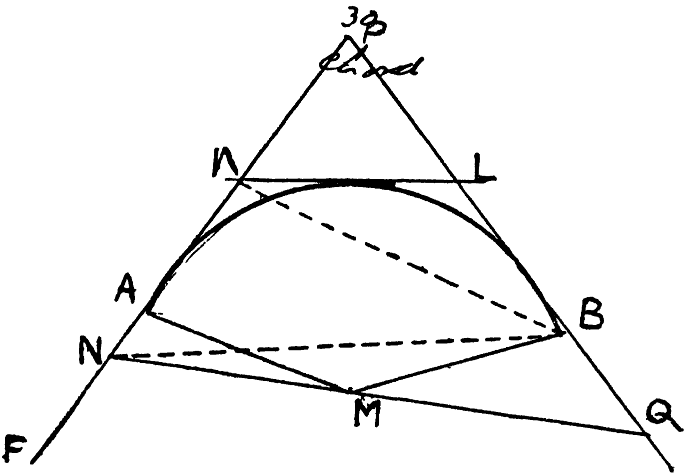
Half length of curve = ·000582 R (5400 − x) .. ..

Note.—x and A in the preceding formulæ must be expressed in minutes.

Table showing degree and radius of curves, chord 100 *feet.*

Angle of deflection.		Radius.	Deflection distance.	Tangent distance.	Middle ordinate.
Degrees.	Min.	Feet.	Feet.	Feet.	Feet.
0	30	11459	·873	·436	·109
1	0	5730	1·745	·872	·218
1	30	3820	2·618	1·309	·327
2	0	2865	3·490	1·745	·436
2	14	2566	3·897	1·948	·487
2	30	2292	4·363	2·182	·545
2	52	1999	5·003	2·501	·625
3	0	1910	5·235	2·618	·654
3	20	1719	5·817	2·908	·727
3	40	1563	6·398	3·199	·800
4	0	1433	6·980	3·490	·873
4	20	1323	7·561	3·781	·945
4	40	1228	8·143	4·072	1·018
5	0	1146	8·724	4·363	1·091
5	20	1075	9·305	4·654	1·164
5	40	1012	9·880	4·945	1·236
6	0	955·4	10·47	5·235	1·309
6	20	905·1	11·05	5·526	1·382
6	40	859·9	11·63	5·817	1·455
7	0	819·0	12·21	6·108	1·528
7	20	781·8	12·79	6·398	1·600
7	40	747·9	13·37	6·689	1·673
8	0	716·8	13·95	6·980	1·746
8	30	674·7	14·82	7·416	1·855
9	0	637·3	15·69	7·852	1·965
10	0	573·7	17·43	8·724	2·183
11	0	521·7	19·17	9·596	2·402
12	0	478·3	20·91	10·47	2·620
13	0	441·7	22·64	11·34	2·839
14	0	410·3	24·37	12·21	3·058
15	0	383·1	26·[illegible]1	13·08	3·277

Example.—Radius of curve 25 chains, chainage of K from starting point =6 miles 67·3 chains, KL = 6·632 chains, angle LKN = 172°-30′-30″- ∠QLK=168°-3′-30″ Deflection right chord=1 chain.



To find the apex and deflection angle

172°-30′-30″
168°-3′-30″

340°-34′-0″
180°-0′-0″

Apex angle=160°-34′-0″. Deflection=19°-26′.

Tangent distant=2500×cot 8°-17′=428·08 ft.

∠KLP=180°—168°-3′-30″= 11°-56′-30″.

∠PKL= 7°-29′-30″.

$$KP = 663{\cdot}2 \times \frac{\sin 11°\text{-}56'\text{-}30''}{\sin 160°\text{-}34'\text{-}0''} = 412{\cdot}48 \text{ ft.}$$

Note.—As the apex angle is above 90°, use its supplement, *i.e.*, 19°-26′.

$$\text{Similarly } \angle P = 663{\cdot}2 \times \frac{\sin 7^\circ\text{-}29'\text{-}30''}{\sin 19^\circ\text{-}26'\text{-}0''} = 259{\cdot}9 \text{ ft.}$$

Hence KA $=428{\cdot}08-412{\cdot}45=15{\cdot}63$ ft.

$\angle B=428{\cdot}08-259{\cdot}9=168{\cdot}18$ ft.

to be set off from K and L both away from P to fix A and B.

M. ch. M. ch.

$\therefore$ chainage of starting point A $=(6\text{-}67{\cdot}3)-(15{\cdot}63')=6-67-14{\cdot}3$ ft.

$$\text{Sin tangential angle} = \frac{\text{half chord}}{\text{Radius}} \quad \frac{50}{2500} \quad \bullet$$

$\therefore$ tangential angle $=1^\circ\text{-}8'\text{-}46''$ approx.

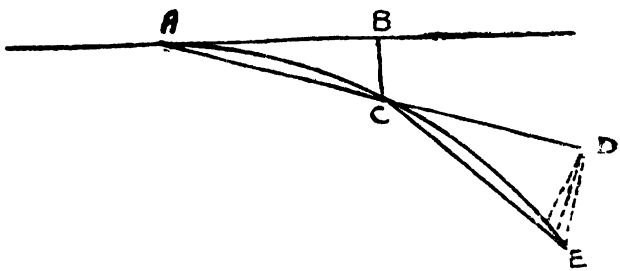
The first chord must be $85{\cdot}63$ ft. to make the chainage 6 miles-68 chains.

$$\text{Angle for this chord} = \frac{85{\cdot}63}{100} \times 68{\cdot}76 = 58\ 87'$$

$$(\text{tangential } \angle = \left(1719 \times \frac{1}{25}\right) = 68{\cdot}76).$$

No.	Chord.	Angle.	Chainage.	REMARKS.
			M. ch.	
1	..85·6	0—58·87 1— 8·76	6—68	
2	..100	2— 7·63 1— 8·76	69	
3	..100	3—16·39 1— 8·76	70	
4	..100	4—24·15 1— 8·76	71	
5	..100	5—33·91 1— 8·76	72	— new station.
6	..100	6—42·67 1— 8·76	73	
7	..100	7—51·43 1— 8·76	74	
8	..100	9— 0·19 1— 8·76	75	
9	..62·3	9—43·0	6-75-62·31	

Ranging Curves by offsets.



$$\text{1st offset} = \frac{(Ac)^2}{2\ \text{radius}}$$

$$\text{Second and subsequent offsets} = \frac{(CE)^2}{\text{Radius.}}$$

A B=AC and CD=CE.

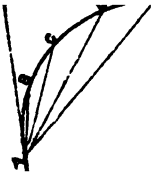
Chord=1 chain (66′).

Table of Offsets for Railway Curves (1st offset.)

Radius of curve.	Offsets in inches.	Radius of curve.	Offsets in inches.	Radius of curve.	Offsets in inches.	Radius of curve.	Offsets in inches.
Chains.		Chains.		Chains.		Chains.	
5	79·2	60	6·6	145	2·73	240	1·65
6	66·0	65	6·09	150	2·64	250	1·58
7	56·87	70	5·65	155	2·55	260	1·52
8	49·5	75	5·28	160	2·47	270	1·46
9	44·0	80	4·95	165	2·40	280	1·41
10	39·6	85	4·65	170	2·32	290	1·36
11	36·0	90	4·4	175	2·26	300	1·32
12	33·0	95	4·16	180	2·20	310	1·27
15	30·46	100	3·96	185	2·14	320	1·23
20	19·80	105	3·77	190	2·08	330	1·20
25	15·84	110	3·6	195	2·03	340	1·16
30	13·2	115	3·44	200	1·98	350	1·13
35	11·31	120	3·3	205	1·93	360	1·1
40	9·9	125	3·16	210	1·88	370	1·07
45	8·8	130	3·04	220	1·80	380	1·04
50	7·92	135	2·93	225	1·76	390	1·01
55	7·20	140	2·82	230	1·72	400	·99

For second and subsequent offsets double the value.

To Set out Curve by Theodolite.



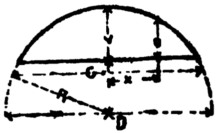
Adjust the theodolite at A and fix the angle PAB, measure AB=100 and fix a peg at B. Again fix angle BAC=PAB and B C=100 and so on. Find the tangential angle from the table.

Table of Tangential Angles for the following Radii, Chord =100 *ft.*

Radius of curve.	Tangential angle.	Radius of curve.	Tangential angle.	Radius of curve.	Tangential angle.	Radius of curve.	Tangential angle.
Chains.	d. m.	Chains.	d. m.	Chains.	minutes.	Chains.	minutes.
2	14—19·5	18	1—35·50	34	55·55	50	34·38
3	9—33·00	19	1—30·47	35	49·11	51	33·70
4	7— 9·75	20	1—25·95	36	47·75	52	33·05
5	5—43·80	21	1—21·85	37	46·45		
6	4—46·50	22	1—18·13	38	45·23		
7	4— 5·57	23	1—14·73	39	44·09		
8	3—34·87	24	1—11·62	40	42·97	*M. fr.*	
9	3— 1·10	25	1 - 8·76	41	41·92	1—0	32·55
10	2—51·90	26	1— 6·11	42	40·92	1—1	28·93
11	2—36·27	27	1— 3·66	43	39·97	1—2	26·04
12	2—23·25	28	1— 1·39	44	39·06	1—3	23·67
13	2—12·23	29	0—59·25	45	38·20	1—4	21·70
14	2— 2·78	30	0—57·30	46	37·36	1—5	20·02
15	1—54·60	31	0—55·45	47	36·57	1—6	18·60
16	1—47·43	32	0—53·71	48	35·81	1—7	17·36
17	1—41·11	33	0—52·09	49	35·08	2—0	16·27

Note.—d=degrees, m=minutes, *M*=miles, *fr.* = furlong.

Rules for the Versed Sines and ordinates of Curves.

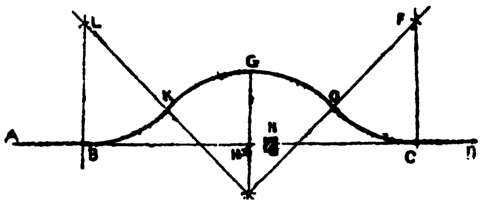


Versed Sine $V = R - \sqrt{R^2 - (\frac{1}{2}c)^2}$.

Diameter of circles $D = \frac{(\frac{1}{2}c)^2}{V} + V$

Length of ordinate $O = \sqrt{R^2 - x^2} - (R - V)$

CURVE OF DEVIATION



Method of deviation from the straight path, in order to avoid buildings, etc., coming into the way.

Let ABCD be a straight portion of the road and N the building to be avoided. Measure oft HG some distance when the building can be safely avoided, from G draw an arc O G K, whose radius is equal to a mile (minimum), and also draw two arcs BK and OC of the same radius to meet the straight line in B and C, then the lines EL and EF which join their centres will pass through points K and O.

Let r = radius.

LB = GE = FC.

Let d = required deviation = HG

then $BH = HC = \sqrt{d\,(4r - d)}$

and the arcs BK, KG, GO and OC are $\sqrt{d\,r}$

EXAMPLE.—At the point A the straight line has been deviated to the right at an angle of 28°-40′. It was considered advisable to join the tangents by 4° curve. The chainage at A = 14827 ft.

Radius for 4° curve = 1433 ft. (see table).

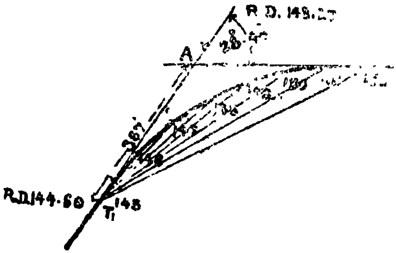
Length of tangent $= 1433 \times \tan. \frac{28°.44}{2} = 367'$.

Length of curve $= 100 \times \frac{28°.41}{40} = 100 \times \frac{28{\cdot}73}{4} = 718$ ft.

The chainage at the beginning of curve
$=14827-367=14460'$
and chainage at end of curve $= 14460+718' = 15178'$
As the pegs are at 100′ apart, the curve begins after 144 pegs+60 ft.

Central angle (apex) for $40' = \frac{40 \times 4}{100} = 1°\text{-}36'$ R D=148·27.

tangential angle $= \frac{1°\text{-}36''}{2} = 48'$



Set the theodolite at T_1 to read 1°-12′. Sight A. Fix the lower plate and adjust the upper plate 2° and fix a flag in that direction and fix peg No. 145 at 40′ from T_1

Then unclamp the upper plate and set at 4°. Fix a flag in this direction at 100′ peg No. 145 and peg No. 146 and so on till the peg 151 is reached. After which 78 ft. is left for which tangential angle

$= \frac{78 \times 4}{100 \times 2} = 1{\cdot}56°$ or 1°-34′

The angles will be as follow :—

0° —48′=145
2° —48′=146
4° —48′=147
6° —48′=148
8° —48′=149
10° —48′=150
12° —48′=151
14° —22′=T_2

The last angle $=\frac{1}{2}$ (28°-44′), therefore the process is correct.
The direction of T_1 A has been assumed O.
If taken as 2°-48′ *i. e.*, 1°-12′ it will be as follows :—

2° —	145
4°	146
6°	147
8°	148
10°	149
12°	150
14°	151
15° -34′	T_2

(15°-34′)—(1°-12′)=14°-22′

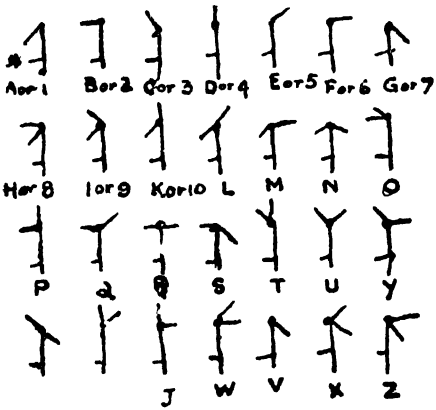
Value for different degrees of Curvature.

A	2°	4°	6°	8°	10°	20°	30°	40°	50°	60°
B	1°	2°	3°	4°	5°	10°	15°	20°	25°	30°
R	2865	1433	955·4	716·8	573·7	287·9	193·2	146·2	118·3	100·0
V	·436	·873	1·309	1·746	2·183	4·374	6·583	8·816	11·09	13·40
T	50·01	50·03	50·07	50·12	50·19	50·77	51·76	53·21	55·17	57·74

A=central angle B=tangential angle

R=radius in feet V=versed sine T=length of tangent in feet= R×tan B

Sempahore Signals, English Standard



The signals can be made by a man moving his arms. For long distances a flag can be held in each hand.

The lower arm simply shows to right of signaller.

Casella's gradient Telemeter Level.

This instrument records linear distances, gradients and difference of lever by one and the same observation without the use of tape or chain. It is similar in construction to y level, but with an addition of circle, on which are marked the gradients from 1 in 1200 to 1 in 10.

The principle of the instrument is that the telescope is horizontal only when the index is at 0. The construction of the instrument differs from that of the y level in that the support for the "Y" which carry the telescope is inclined and that there are two axes.

Reducing and Enlarging Maps.

(1) *By means of proportional compass.*—Distances are measured from the map by means of the points at one end of the divider and are plotted on the copy with the opposite pair of points. The ratio of these distances can be fixed by the slide scale marked on the instrument.

(2) The ***Pantograph*** consists of frame work of several pieces of wood or metal so joined as to form a parallelogram. It rests upon three points, one of which A is fixed and the other two B and C are movable. These two points are in such a position that they will trace exactly similar figures. Any one of the three points can be a fixed point. These instruments are usually provided with scales indicating the proper setting for various reductions or enlargements.

Eidograph is also used for reducing and enlarging drawing in any proportion.

Judging Distances from Sounds.

On a still day distant sounds may be heard—

Human voice	150 yards.
Military Band	About 3 miles.

Decrease af Temperature with Altitude.

Rate of decrease of temperature is 1°F. from 273 ft. in summer to 474 ft. in winter.

BUILDING MATERIALS.

STONES.

Name.	Locality.	Uses.
Granite or Gneiss	Ajmere, Bangalore, Burma Dalhousie, Jubblepore, Mysore and Madras.	Building masonry paving and road metalling.
Basalt or Trap..	Bombay, Central India, C. P., Madras and Poona.	Rough masonry, floor slabs and road-metal.
Limestone ..	Bombay, Shahabad Flags, Hyderabad, Jubblepore, Madras, Sarai Kala and Trichinopoly.	Floorings, sills, terraced roofs and road-metal.
Sandstones ..	Agra, Bengal, Delhi, Dharmsala, Gwalior, Jubblepore, Mysore, Rawalpindi, Saugor.	For all purposes of building works.
Slates ..	Chamba, Dalhousie, Rajputana and S. India.	Chiefly for roofing and flooring.
Marbles ..	Gwalior, Jaipore, Kashmere and S. India.	For ornamental building works.
Latrite ..	Belgaum, Mahableswar, Orissa and Western Coast of India.	Suitable for road-metal.
Kankar ..	All over India ..	For making lime and for road-metal.

SCALES OF HARDNESS OF MINERALS.

1. Talc.
2. Rock salt.
3. Calcite.
4. Flouspar.
5. Apatite.
6. Felspar.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond.

Each mineral in the above list can scratch those preceding and may itself be scratched by those succeeding.

2.—BRICKS.

Qualities of a good brick.— A first-class brick is distinguished by its uniform colour, evenness of surface, sharpness of edges and compactness of structure. It should give a clear ringing sound when struck and should not crumble to powder when scratched with nails and absorb more than 1-10th of its weight when soaked in water for 24 hours.

Usual sizes of bricks :—

Old Indian bricks	$12'' \times 6'' \times 2\frac{1}{2}''$
Punjab Irrigation	$10 \times 5 \times 3$
Punjab P. W. D.	$9 \times 4\frac{1}{4} \times 2\frac{3}{4}$
Bengal P. W. D.	$9\frac{1}{2} \times 4\frac{3}{4} \times 2\frac{3}{4}$
Madras	$9\frac{3}{4} \times 4\frac{3}{4} \times 3$
Bombay	$9 \times 4\frac{1}{4} \times 2\frac{1}{2}$
London	$8\frac{3}{4} \times 4\frac{1}{2} \times 2\frac{1}{2}$

The bricks are either slope or sand moulded. By the former method the mould is dipped in water every time it is used to prevent the green bricks from sticking to the mould. By the second method it is sprinkled with sand. Bricks made by this method have a better surface and bricks used in all Government works are specified sand moulded.

Brick moulds are generally made about 1-10th larger than the size of the bricks to be made to allow for shrinking on drying and burning : the exact size depends upon the nature of the clay used.

Best clay for bricks.

(1) should not be too plastic or too sandy ;
(2) should be free from mixture of kankar or lime;
(3) should not contain any mixture of saltpetre.

Test of Clays.— Test the clay by making a few bricks out of it and allow them to dry in the open air. If the bricks crack it shows that the earth is too plastic and needs to be mixed with sand. If they break easily when thrown down on ground they are brittle and show too much sand and are apt to fuse in burning, *i. e.*, become *Jhama*.

Brick-making.—The following operations are performed in brick-making :—

(1) The preparing of brick earth, (2) the tempering, (3) the moulding, (4) the drying and (5) the burning.

The bricks are moulded by hand or by machine.

Hand moulding is either ground moulding or table moulding. Table moulded bricks have a more regular shape and a smoother surface than ground moulded.

Brick burning.— In India, bricks are burnt in (1) clamps or (2) kilns.

In the clamp (*pazawah*) the green bricks and fuel are placed in alternate layers for burning bricks in open air ; and in the kiln (*bhatha*) the bricks are stacked without any fuel and burnt from fire-places, arranged below the stack in which fires are lighted and kept up with fresh supplies of fuel till the bricks are burnt. The kiln has a permanent enclosing wall inside which the bricks are arranged over flues whereas the clamps have no enclosing walls but they are merely a heap of alternate layers of bricks and fuel. Clamps are used when only one small supply of bricks are required.

The fuel used in kilns is either coal or firewood and in clamps is manure (*khath*), dried cow-dung, grass or town sweepings (*kura*) with sometimes a little wood in the lower layers. Coke is also used where obtainable.

The fire cannot be regulated once the clamp is started and the outturn of bricks is uneven. It takes longer time to burn equal quantities of bricks than kiln hence unsuitable if the bricks are required at once. The out turn of good bricks is, however, better than kiln owing to the gradual burning and cooling.

Brick kilns: Bull's Patent Improved Trench Kiln Construction.—The usual sizes are—

	Radius.		Width.	No. of Chambers.	Length of Chambers.		Length of Chimneys.		Out-turn in season in lacs.
	Outer.	Inner.			On outer wall.	On inner wall.	Outer.	Inner.	
1	57′·0	42′	$14\frac{3}{4}$	20	18	$13\frac{1}{4}$	35	..	15
2	73′·0	48′	25	24	19	$12\frac{1}{2}$	35	24	30
3	114′·0	89′	25	40	18	14	35	30	60

TYPE OF BULL'S KILN IMPROVED PATTERN (NEW CAPITAL WORKS, DELHI).

Size:—187′·4″ outer dia. 134′·0 inner dia., 26′·8″ width and 7′·6″ depth.

Consists of 32 chambers, each chamber containing 27,500 bricks and the total turn out of the kiln is 8 lakhs bricks in one complete circle.

Labour required for—

(1) Moulding—30 moulders, 90 coolies and one pair of bullocks for drawing water from existing wells.
(2) Loading—40 coolies and 4 beldars.
(3) Unloading—40 coolies and 4 beldars.
(4) Firing—one mistry and two burners, two per each 12 hours.

One moulder can mould 600—1000 bricks in a day with the help of 3 other coolies.

Tools and plant for one kiln:—

For moulding.—40 phaoras, 40 brick moulds, 40 buckets 12″, 40 sand sieve and 400 wooden pallet boards.

For burning,—2 chimney base plates, 1 chimney 35′ high for outer circle, 1 chimney 30′ high for inner circle, 8 chimney group of wire rope, 6 hurricane lanterns, 1 pair tongs to set feed-hole mouth-pieces, 2 coal ladles for front firing, 2 coal ladles large for back firing, 4 shook iron for lifting feed-hole covers, 70 C. I. feed-hole mouth-pieces, 70 C. I. feed-hole covers, 3 sets of 14 each damper sheet iron, 3 keys for damper, 6 chimney hole covers, 4 chimney hole dampers.

8 iron rail sheets, 6 bridges, 4 crow bars to lift chimney, 4′×1½″; 2 iron rods 12′ long to rake coal, 2 wooden templates to load bricks in kiln, 4 coal tubes iron 42 covers for starting fire, 2 ladders, wooden for loading and unloading kiln, 1 time-keeper, 2 sledge hammers, 2 coal shovels and 1 screen 6′×3′×¼″ mesh.

The following figure shows the type of Bull's Kiln Improved Pattern—

Construction of kiln.—In hard soil the trench may be unlined, in soft soil the walls should be of burnt bricks, and in damp sandy soil the excavation should not exceed 4′. The damper space and combustion chambers are shown in Fig. 3. The chimney is 35 ft. high, mounted on a cast-iron base plate on wheels, the axles of which radiate so that they will travel round the wall. When two chimneys are used, the chimney opening on the inner sides will be opposite those on the outer but will be only 2′-6″ in width, and the chimney will be only 25 ft. high. The upper outlet into the chimney is controlled by an adjustable damper. Cross dampers, Fig. 5, are required to divide off the various sections of the kiln. They should be made 2″ smaller than the width of trench to prevent the centre key jamming. When fixing the cross dampers, great care must be taken to make them fit tightly. It is a good plan to drop a little dust or fine earth down behind them to close up any possible interslices owing to the irregularities in the floor.

There are 5 combustion chambers to each damper length. The feed-holes are formed with the aid of templates shown in Fig. 8, there should be a feed-hole over each of the two outer walls, after that over each alternate wall.

9″ of earth is evenly spred. The earth should be as light and impervious to air as possible.

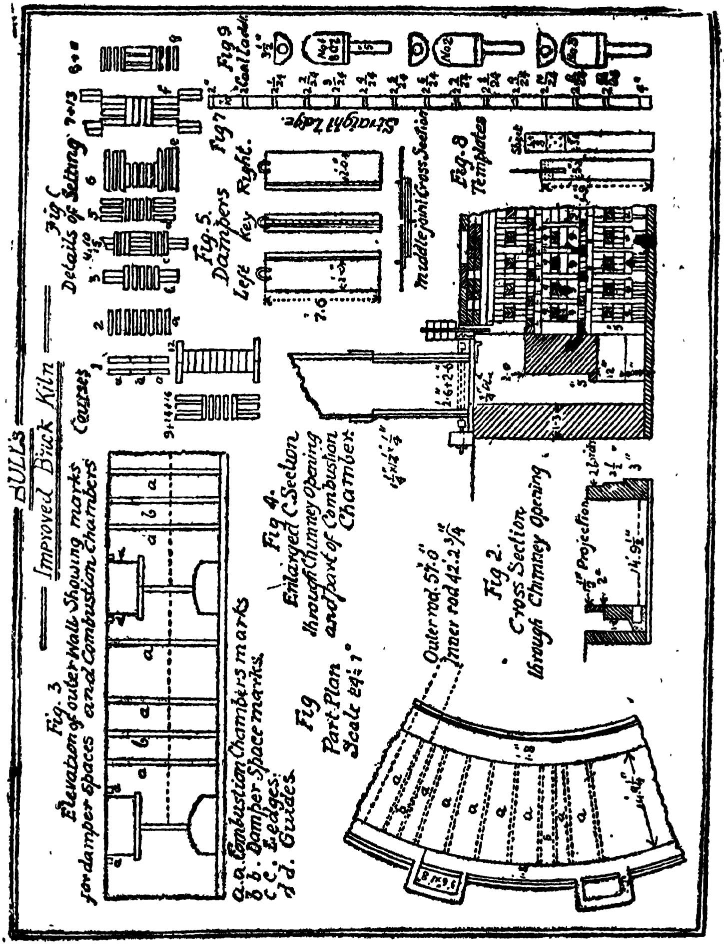
Firing.—To start the firing, a temporary cross wall, see Fig. 1 is built, with furnaces for bottom firing.

About 150 maunds of coal is required for starting the firing of a 14 wall kiln and 250 for a 24 wall. For top firing good dust coal is required.

4 sizes of ladles are required for top firing, see Fig. 9.

Wood Fire Kiln.—No furnaces are required for starting, wood is packed to a depth of 3 ft. in a combustion chamber 1′ wide and lit through fire holes, 9″ square at the bottom of the wall.

The feed-holes should not be less than 14″ square. The chimney can be kept two or 3 lines further away from the burning, than in the case of coal firing. When dry wood is procurable this method of starting a kiln may be used with advantage for a coal fired kiln, and the furnace bars saved.


BULL'S
Improved Brick Kiln
Fig. 3
Elevation of outer Wall Showing marks for damper spaces and Combustion Chambers
a.a. Combustion Chambers marks
b.b. Damper Space marks
c.c. Ledges
d.d. Guides
Fig
Part Plan
Outer rad. 57.8
Inner rad 42.2 3/4
Fig 4.
Enlarged C Section through Chimney Opening and part of Combustion Chamber
Fig 2.
Cross Section through Chimney Opening
Courses
Fig 6
Details of Setting
Fig. 5.
Dampers
Left
Key
Right
Middle joint Cross Section
Fig 7
Straight Edge
Fig 8
Templates
Fig 9

LIME.

There are two kinds of lime in use : white stone lime and kankar lime which is more or less hydraulic.

A 100 maunds of Meani white lime will produce as much as 56 maunds of quick lime, which, when slaked with an equal weight of water, expands to about 2¼ times its bulk, weighing 36 lbs. per c. ft. White lime should be used fresh from the kiln, if allowed to slake, it absorbs Co_2 and becomes useless for mortar.

Kankar lime, clamp or kiln burnt from clean kankar will be ground till no residue is left when the lime is passed through a screen of 64 meshes per sq. inch; and only freshly ground lime should be used for mortar.

Burning of Limestone.—The system of calcination may be (1) continuous or (2) intermittent.

In the 1st system the fuel and limestone are placed in alternate layers and the burnt lime is gradually removed from the bottom of the kiln and fresh limestone and fuel added on the top.

The 2nd system consists in firing, burning and discharging a kiln full of limestone each time. There is a waste of fuel. Each operation takes about one week.

Limestones are calcined in clamps like bricks. The clamp consists of a heap of alternate layers of limestones and fuel, having fire holes below and covered up with clay to prevent the escape of heat. It is best burnt with coal. If fire-wood is used the small particles of lime get mixed up with ashes and hence poor quality of lime is the result.

Charcoal or wood may be used for firing the kiln. The stone or kankar must be cleaned of earth and other impurities and broken to a 2″ gauge.

Alternative practicable methods of packing the kiln are as follows:—

(*i*) Pack the stone metal in 3″ layers with ¼″ coaldust between layers.

(*ii*) Pack a 4½′ foundation of wood followed by alternate 2′ layers of metal and wood. Cover the top with mud platered over with a 2′ diameter hole in the centre.

In method (*i*) wood or cowdung must not be mixed with the coaldust.

10 cubic feet of coaldust are required for 100 cubic feet of stone metal. 1 ton of coaldust measures about 40 cubic feet.

For economy, the burning should proceed continuously, the kiln not being allowed to become cold.

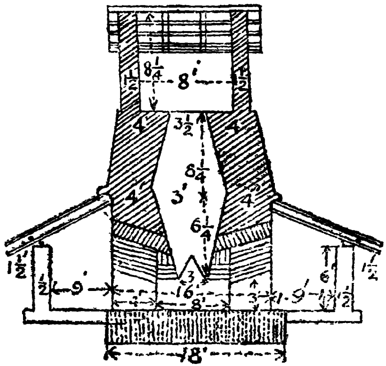
The burnt material is drawn out daily, and replaced by fresh material and coaldust at the top. When the burnt material is withdrawn, it is handpicked; overburnt lumps are discarded and underburnt ones reloaded in the kiln. The remaining material is slaked or ground fine in a mill.

A suitable type of kiln is given below.

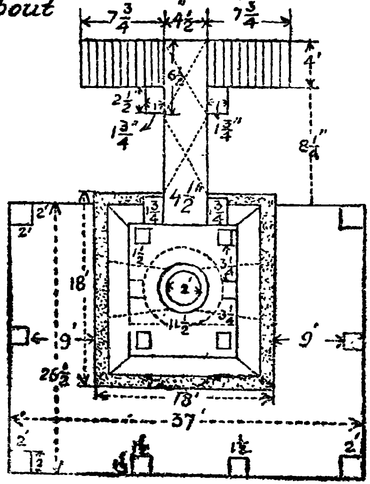
LIME KILN

This may be built Singly or Several can be built together in a black, according to re-quirements. each kiln will burn about 150 cubic feet perday

SECTION



PLAN



COMPARATIVE TESTS ON PORTLAND CEMENTS.

Analyses.	"BBB" Brand, Bundi (May 1924.)	"Castle" Brand, Katni.	"Hand" Brand, English.	"Five Rivers" Brand, Punjab (August 1924).
SiO_2 ..	24·50	21·86	21·98	21·16
Insol, Residue	0·72	0·65	0·44	0·32
$AlO_{\frac{2}{3}}$ ..	4·35	6·55	6·34	7·03
$FeO_{\frac{2}{3}}$ ..	1·72	2·96	4·26	2·78
Cao ..	64·40	63·13	63·56	63·26
Mgo ..	1·67	1·96	1·18	1·91
SO_3 ..	1·19	1·59	1·51	1·95
Loss on Ignition	1·07	1·33	0·70	1·41
Alks by difference.	0·38	..	0·03	0·18
	100·00	100·03	100·00	100·00
Hydraulic Modulus.	2·52	2·58	2·61	2·62
Physical Tests Residue				
on 240×240	11·5	17·5	11·0	12·5
,, on 200×200	7·5	12·5	7·0	7·5
,, on 180×180	4·5	8·0	4·0	5·0
,, on 76×76	0·08	0·35	0·11	0·06
Soundness expansion *m/m*	0·5	0·2	0·7	0·7
Setting time initial mins.	135	135	90	115
Final mins. ..	180	185	130	190

	Neat.	Sand.	L. B. Sand.	Neat.	Sand.	L. B. Sand.	Neat.	Sand.	L. B. Sand.	Neat.	Sand.	L. B. Sand.
Tensile Tests:												
3 days ..	707	29[illegible]	382	749	374	378	646	243	256	720	398	441
7 days ..	826	366	475	798	388	423	687	293	310	709	450	500
28 days ..	877	481	539	807	490	477	717	411	418	775	485	501
90 days ..	845	547	579	796	532	518	715	560	452	816	499	526
	Hand.	Machine.		Hand.	Machine.		Hand.	Machine.		Hand.	Machine.	
Crushing Strength: 7 days	4400 lb.	4700		4040	4260		3380	3700		4535	4415	
28 days	6000 ,,	6500		5370	5830		4450	5080		6050	6060	
90 days	6770 ,,	7390		6350	6530		5925	5995		6580	6495	
Flourcmeter Test. Flour%	65·1			55·5			63·0			59·9		
Proportion of water used in gauging.	Neat.	Sand.		Neat.	Sand.		Neat.	Sand.		Neat.	Sand.	
	24·5%	10·5%		25·5%	10·0%		23·0%	9·0%		22·5%	8·5%	

TIMBER.

(1) The greatest strength is generally to be found between the centre and the sap and timber that is straight in its grain is strongest.

(2) In the same class the heavier the better.

(3) The fibrous tissues should not clog the teeth of the saw, or show woolliness at a freshly cut surface.

(4) The timber from which resin has been extracted is not good, but in resinous timber that with the least resin in its pores is strongest.

(5) The lower part of the tree gives the stronger timber.

(6) The older the timber the better.

(7) Beam or sawn timber having through knots should be rejected.

(8) A dull chalky appearance when cut is a sign of bad timber.

(9) Dry timber is stronger than the timber saturated with water.

(10) The heart is weaker than exterior parts and the bark is weaker than the rest.

(11) Density of timber is proportional to the tune in growing.

TIMBER.

Name.		Weight per c. ft. in lbs.	Coefficient of stiffness.	Coefficient of strength.	Locality.	Uses.
ANJELY	..	38	3,900	604	Western Ghats and Burma	House and Ship building.
BABUL	..	54	4,000	880	All over India.	Boats, Curbs, wheels, fuel.
BER	..	58	3,500	600	Northern India and Punjab.	Well curbs, axles of cart, fuel.
CHIR	..	38	2,500 to 3,500	400 to 600	In Himalayas from Bhutan to Afg.	House building, furniture.
DEODAR	..	40	1,800 to 2,500	300 to 500	On the mountains of Himalayas.	Beams, burgas, boxes, etc.
HALDU	..	43	..	612	In all forests of India and Burma.	Planking, furniture, cabinet work.
JAMAN	..	48	2,700	6[illegible]0	Northern India	
JARRAH	..	55	1,100	600	Imported from Australia.	Sleepers, paving blocks, piles, etc.
KAIL	..	32	700	700	Himalayas at altitude 6,000—12,500	Sleepers, poles, matches and match boxes.
MANGO	..	42	3,000	500	Northern India	House building, planking, etc.
OAK	..	54-64	..	491—670	On mountains of Himalayas.	Sills, stairs, floors, joinery.
SAL	..	55	4,000	800	Sub-Himalayan tract	House-building, piles, posts, boats.
SHISHAM	..	50	3,500	700	Nearly all over India.	Handles, high-class building work.
SIRIS	..	56	..	532—777	Sub-Himalayan tract.	Boxes, beams, boats, planks, etc.
SAJ	..	..	..	..	Central India and Burma.	House-building and fuel.
TEAK	..	42 to 45	3,900	800	Burma, C and S. India.	Sills, furniture, sleepers, ships.
TOON	..	34	2,500	465	Assam, Burma, W. Ghats.	Door panels, furniture, planking.
WALNUT	..	44	..	..	On Hills of U. Burma and Himalayas.	High-class furniture and Cabinet work.

Before bringing the timber in use it should be well seasoned, *i. e.* free of sap otherwise it will rot.

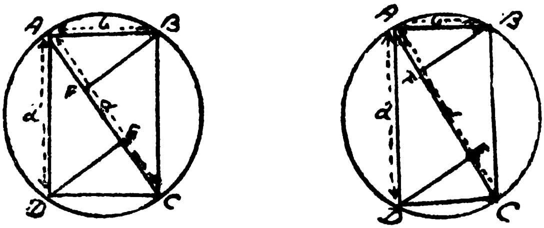
Rot is of two kinds (1) Dry rot, (2) Wet rot.

(1) Dry rot is a state of decomposition of felled timber by dry rot fungi. When the growth is allowed to proceed unchecked the timber crumbles to powder.

(2) Wet rot is a decomposition of the issue of a felled or standing tree, set up by the access of water through cuts in the bark. Timber that has been lying long in the rivers and subjected to alternate wet and dry reaches soon the stage of wet rot.

Cutting the strongest beam from a round log (approx.).

Divide the diameter into three equal parts and draw perpendiculars FB and ED at E & F to cut the circle at B and D. Join ABCD. This is the required beam; its depth $d' = \cdot 816d$ and breadth $b = \cdot 577d$.



Cutting the stiffest beam from a round log:—

Divide the diameter into 4 equal parts and draw perpendiculars at E and F and cut the circle at B and D. Four points A. B. C. D. joined will give the beam d' being $\cdot 866d$ and $b = \cdot 5d$.

CAST IRON.

Cast iron is made from pig iron, the metal in this condition contains 2 to 6 per cent. of carbon, is hard and crystalline, very brittle and weak in tension, but strong in compression. Its density averages 450 lbs. c. ft. *Uses.*—Cast iron is employed for pillar bases columns and stanchions, lintels and bressummers, gutters, rain water soil pipes; low pressure heating pipes; pockets for floor beams and roof rafters; external gratings, fire grates and accessories; gates and railings; drain pipes, manhole covers, etc. Also for ornamental work in panelled fallings to masonry fascades.

WROUGHT IRON.

Good wrought iron contains very little carbon the limiting being ·15 per cent. Its density is about 480 lbs. per c. ft.

Uses.—For bolts, strops, large hinges, gutter brackets and beam stirrups, tie rods, connecting plates and holdfasts, low and high pressure; heating pipes and steam pipes, heavy door and window furniture, railings, entrance gates, grelles, etc., provide a fine and artistic field for the use of wrought iron.

It oxidises rapidly on exposure to damp. In fittings and furniture it is usually japanned while hot, where this cannot be done wrought iron should be painted before fixing and immediately on completion.

Carbon varies from ·15 to 1·5 per cent.

STEEL.

Mild steel contains not more than ·5 per cent. of carbon and has a density of about 490 lbs. per c. ft.

It is used in the production of British Standard sections.

Cast Steel.—Is a crystalline, hard variety due to larger percentage of carbon, and is used chiefly for the production of keen edged cutting tools.

Bressemer Steel.—Is a mild steel and is used in castings for the bases of large stanchions, bridge bearings and for rolling into structural sections.

Uses of Steel.—Mild steel is employed for the standard sections, used in floors, roofs and stanchions, reinforcing bars in concrete, tension members in composite trusses, good bolts and fixings, screws, metal, furniture and fittings, hinges, locks and casements.

STRENGTH.

Material.	Compression.	Tension.	Shear.	Bearing.	
Steel	7·5	7·5	5·5	11·0	tons per sq. inch.
Wrought iron ..	5·0	5·0	4·0	7·0	„ „ „ „
Cast iron ..	8·0	1·5	1·5	10·0	„ „ „ „

TEST FOR METALS.

Cast iron should be struck lightly with a steel hammer which easily ensures detection of cracks or flaws by the sound produced.

Small beams 1″×1″×1′ for clear span or 2″ deep × 1″ broad × 3′ clear span are usually tested for bending; they should roughly support 1 ton and 1½ tons at centre respectively before breaking and the fracture should be sharp, clean and crystalline.

Steel is tested mechanically to comply with the British Standard Specification, which include tension, elasticity and both cold and hot bending.

EXPANDED METAL.

This material is formed by cutting and expanding either plain sheets or ribbed sheets of steel. The prepared sheets are known as Diamond mesh and Rib mesh expanded steel. Diamond mesh varies from 1½″ to 6″ across the short way of the mesh and is obtainable in sheets from 4 ft. to 8 ft. long × 16 ft. wide or *vice versa* with great variations in the thickness of strands and tensile strength.

Rib mesh is produced in sheets from 16″ to 64″ wide and 10 ft. to 24 ft. long with meshes 2″ to 8″ square.

When used as reinforcement to concrete slabs these expanded sheets should be placed with the rib, or the long way of diagonal the short way of the slab, because the greater stresses occur in that direction.

STEEL ALLOYS.

Name.	Uses.
VANADIUM STEEL	Castings for engine frames, forgings, axles, springs, etc.
NICKEL STEEL	In long span bridge construction, axles, shaftings, bearings, etc.
MANGANESE STEEL	In rails, on sever curves, safes, stone screens, crusher jaws and rollers, etc.
CHROME STEEL	For chisels, drills, saw blades, files, bearing, balls and rollers, etc.
TUNGSTEN STEEL	Used in magnets and to some extent in lathe tools.

BRONZE ALLOYS.

Name.	Copper.	Tin.	Zinc.
Soft gun metal	16	1	..
Hard gun metal for bearings	16	2	1
Mathematical Instruments	12	1	..
Pumps (very tough)	32	3	1
Pump plungers	14	1	1
Locomotive bearings	112	13	½
Engine bearings	64	7	1
Bell metal	3 or 5	1	..

BRASS ALLOYS.

Name.	Copper.	Zinc.	Tin.	Lead.
Stop cocks and valves	88	10	2	..
Stop cocks and valves	73	8	7	12
Brass for soldering	8	3	..	..
Muntz metal	3	2	..	..
Brass, various	60—92	8—40	¼-3	½-3
Bronze for lamps..	27	6	1	1

ANTIMONY ALLOYS.

Name.	Copper	Tin.	Lead.	Antimony.
White Bronze	5·5	83·5	..	11
Pewter	..	100	..	17
Type Metal	..	..	3·7	1
White Brass	1	..	7	7

NICKEL ALLOYS.

	Copper.	Tin.	Nickel.
Common German Silver	60	25	15
Better ,, ,,	50	25	25
Electro ..		3·5	

VARIOUS ALLOYS.

Name.	Copper	Tin.	Zinc.	Various.
Silver Bell Metal	80	10	6	4 lead.
Aluminium Bronze	90	..	..	10 aluminium.
Phosphor Bronze	82	10	..	7½ lead, ⅛ iron.
British Coinage Bronze	95	4	1	⅛ nickel, ¼ phosphor.

PAINTS AND VARNISHES.

The object of painting is to protect the materials from the action of heat, gases, moisture and also improve their appearance.

Materials.—The chief material generally used in painting is either white lead or oxide of zinc well ground in raw or boiled linseed oil.

Paints consist of—

(*a*) Base (white lead, red oxide, oxide of iron or zinc white),
(*b*) Carrier (oils).
(*c*) Dryer (red lead, zinc, sulphate and litharge).
(*d*) Colouring pigment (ochre, lamp black and other salts).
(*e*) Solvent (turpentine).

Preparation of Paints.—The base is first ground in oil and then mixed to the required thickness for work in oil or spirits of turpentine. The pigments should then be ground on a flat stone with oil until well mixed and then rendered fluid by the addition of oil or spirits of turpentine and mixed with the base that has already been prepared.

Mixing Paints.—1 cwt. of red metallic paint in a stiff paste requires 3½ gallons of oil and ½ gallon of turpentine, and when mixed well, cover about 6,000 sq. feet in the first coat and about 9,000 sq. ft. in the second coat. Boiled linseed oil should not be put in a vessel which previously contained sweet oil or other non-drying oil without thoroughly cleaning the vessel. One teaspoonful of latter would prevent the former from drying when used with paints.

Dryers.—The best dryers in use for paint are litharge and sugar of lead. The former is for dark and middle tints, the latter for light tints.

Paint will not dry on smoked or greasy surfaces which should be first washed with turpentine or sized.

Painters Primming.—Primming is always the first coat to fill in the pores of wood.

Knotting.—Mix up 1 pint of vegetable naptha, 1 teaspoonful red lead, ¼ or quarter pint Japanese gold size and 5 ounces orange shellac, put them into a warm place and shake until dissolved.

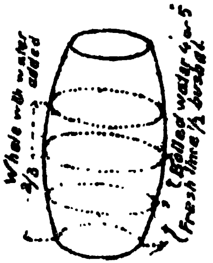
Blistering.—Sometimes paints will blister simply because the coats are too thick. If the wood is quite dry and the paint very good, it will sometimes blister if used too thick. The chief cause is, however, often moisture in the substance painted and wood especially even when it is apparently dry may contain a very considerable amount of moisture, and if painted when in that condition it is prevented from escaping until the warm sun converting it into vapour raises the paint and causes the blister.

Table of Varnishes.

Colour.	Composition.	AMOUNT REQUIRED TO COVER 100 SQUARE FEET IN LBS.								
		New iron work		*Old iron work.*		*New timber work.*			*Old timber work.*	
		1st Coat.	2nd Coat.	1st Coat.	2nd Coat.	1st Coat.	2nd Coat.	3rd Coat.	1st Coat.	2nd Coat.
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Black	Cullin's mixture (made of coal-tar and naphta, sold ready for use)	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	..	..	..	..	..
Black	Ordinary moist ..	$3\frac{1}{4}$	$1\frac{3}{4}$	$4\frac{1}{16}$	$2\frac{1}{2}$	4	$2\frac{1}{8}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{9}{16}$
White	White lead	3	$2\frac{11}{16}$	3	$2\frac{11}{16}$	$4\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{9}{16}$	4	2
Slate	Mixture of white lead 18 lbs. lamp black, 1 lb.	3	$2\frac{11}{16}$	3	$2\frac{11}{16}$	$4\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{9}{16}$	4	2
Red	Red lead	3	$2\frac{11}{16}$	3	$2\frac{11}{16}$	$4\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{9}{16}$	4	2

Table of proportions of paints and oils.

Inside or Outside.	LEAD PAINT. White, Red or Slate.	Boiled linseed oil.	Raw linseed oil.	Turpentine.
(*a*) Inside work ..	28 lbs.	$5\frac{1}{2}$ lbs. $=4\frac{3}{4}$ pts.	$5\frac{1}{2}$ lbs. $=4\frac{4}{5}$ pts.	15 ozs. $=1$ pt.
(*b*) Outside work, as girders ..	28 lbs.	4 lbs. $=3\frac{1}{4}$ pts.	7 lbs. $=6$ pts.	15 ozs. $=1$ pt.



Method of Painting on Walls.

Take ½ bushel of fresh lime, and soak it in boiling water to a depth of 4 to 5 inches and mix well. Take a cask as shown, and fill it ⅔rd with water, add one bushel hydraulic cement and 3 lbs. zinc sulphate (after dissolving in water). The paint is then ready for use.

Oil Painting on Walls.—Can be used on wood, brick or stone, etc.

Ground quicklime (fresh)	1 part.
White sand or fine coal ashes	1 part.
Fresh wood ashes	1 part.

Sieve it through very fine sieve. Mix well dry and add raw linseed oil to bring it to thin consistency. Then it is ready for using with required colours.

The second coat should be thicker than the first coat.

Best White Lead	50 lbs.
Raw linseed oil	4 quarts or 2½ lbs.
Dryer (or litharge)	½ lb.
Finely sifted, sharp clean sand	50 lbs.
Raw Umber	2 lbs.
Add turpentine	½ pint.

Apply with a large brush.

Damp Wall Paints.—Damp wall paints can be applied as ordinary paint. Where the dampness is very bad, it is advisable to put on two coats. It will dry hard, however damp the wall may be. Paint or paper can be safely applied without fear of damp penetrating. It can be made in many colours.

Take 2½ gallons paraffin, 2 gallons benzoline, and 14 lbs. pale rosin. Put them into a can; cork it and shake well, until the contents are dissolved, then add 24 lbs. best Whiting and grind the whole mixture through a paint mill, if possible, and keep airtight to prevent it drying too quickly.

Paints for Black Boards.—Take Shellac one lb., alcohol one gallon, lamp black 4 ozs., powdered emery, 4 ozs. and ultramarine blue, 4 ozs.

Dissolve the Shellac in the alcohol. Place the lamp black, emery and ultramarine blue on a cheese cloth strainer, pour one part of the Shellac solution, stirring constantly and gradually adding the solution until all the powders have passed through the strainer.

The following materials are required to paint 900 s. ft.

	Red lead.	Glue.	Putty.	Pumice stone.	Glass paper.	White lead.	Linseed Oil.	Litharge.	Turpentine.
	Lbs.	Lbs.	Lbs.	Lbs.	Quire.	lbs.	Pints.	Lbs.	Pints.
1. Knotting	·3	·3	..	..	..	·2	..	..	..
2. Stopping	..	..	4	$\frac{1}{2}$	1·0	..	..	..	..
3. 1st coat ..	3	..	..	..	..	15	7	$\frac{1}{3}$	..
4. 2nd coat	..	..	..	..	..	12	3	$\frac{1}{6}$	$\frac{3}{4}$
5. 3rd and following.	..	..	..	..	..	12	3	$\frac{1}{6}$	1
6. Flatting coat.	..	..	..	..	..	3	..	..	3

1. Raw linseed oil is chiefly used for inside work and boiled oil for outside work.

WEIGHT OF MATERIALS.

Weight of one gallon Linseed oil = 9·4 lbs.
,, ,, ,, ,, turpentine = 8·6 lbs.
,, ,, ,, ,, coal tar = 10·1 lbs.
,, ,, ,, ,, pitch = 10·0 lbs.
,, of 1 c. ft. of white lead ground in oil = 252·0 lbs.

MISCELLANEOUS.

I.—*Paint for Wagons and Engines.*

	cwt.	qrs.	lbs.
Chocolate red, dry	0	3	0
Linseed oil, raw	0	0	14
Turpentine	0	0	10
Dryers	0	0	4
Total ..	1	0	0

Sufficient to cover 2,700 to 3,000 sq. ft.

II.—*Olphert's Metallic Paint.*

Olphert's metallic powder (dry) .. .. .. 10 parts.
Linseed oil (raw) .. .. 4 ,,
,, ,, (boiled) .. .. 1 part.
Turpentine .. .. 1 ,,

III.—*Tar and Oil Mixture.*

Coal tar	.. ..	8 parts
Kerosine oil	.. ..	1 part.

Melt together and apply when hot.

IV.—*Formula for inside of tanks.*

White lead ground in oil	.. ..	28 lbs.
Linseed oil (raw)	.. ..	7 „
„ „ (boiled)	.. ..	4 „
Turpentine	.. ..	15 to 16 ozs.

If 1/16th of its part of lamp black is added it will give beautiful slate colour.

V.—*Tar Mixture No. 1.*

Coal tar	.. ..	8 gals.
Pitch	.. ..	10 lbs.
Naphtha oil	.. ..	1 gal.
Slaked lime	.. ..	8 lbs.

Boil fully and apply hot.

VI.—*Tar Mixture No. 2.*

Coal tar	.. ..	672 lbs.	One pound will cover 26 s. ft.
Fresh slaked lime	.. ..	84 „	
Kerosine oil	.. ..	84 „	

VII.—*Formula for cleansing off old paints from iron work.*

Common Suji	.. ..	1 part	One maund is enough for 840 s. ft.
Fresh slaked lime	.. ..	1 „	

VIII.—*Order of Merit of Paint* :—

(*a*) Red Lead paint.
(*b*) "A" Red Lead paint.
(*c*) "B" Red Lead paint.
(*d*) Orange Lead paint.
(*e*) Vermillionette paint.
(*f*) Permanent red paint.
(*g*) Zinc white paint.
(*h*) "A" Zinc white paint.
(*i*) "C" Zinc white paint.
(*j*) Lithopone paint.
(*k*) White Lead paint.
(*l*) "A" White Lead paint.
(*m*) "C" White Lead paint.

Note on Caustic Soda—

When this contains from 70 to 80 per cent. of pure salts, a solution of 2 lbs. caustic soda to 1 gallon of water will remove one coat of paint in 1 or 2 minutes. If left too long on wood-work it does harm, and will shorten the life of the timber considerably. It should be applied with swabs, or rough brushes, made of old rope yarn, or unrefined jute.

Bycycle paint. (1) Amber 8 ozs., linseed oil 4 ozs., asphaltum 1½ ozs., rosin 1½ oz., oil turpentine 8 oz. Heat the linseed oil to boiling point, add the amber, asphaltum and resin and when all melted remove the heat and gradually add the turpentine.

(2) Oil tar 4 ozs., asphaltum 1 oz., resin powdered 1 oz. Mix and dissolve with aid of heat, care being taken to prevent contact with the flame.

Canvas Paints—Buff.—To light stone add: ocher 20 lbs., lemon chrome 3 lbs., extra oil, ½ gallon.

Indian Red.—Indian red 112 lbs., whiting 56 lbs., barytes 63 lbs. half boiled and half raw, oil 6 Gallons, soft soap, 7 lbs.

White.—White lead 224 lbs. refined linseed oil, 15 lbs. soft soap, 7 lbs.

Varnishing:—Varnish is used to protect paint from the effects of the atmosphere and also to give a gloss to the surface.

In the making of varnishes the gums or resins are reduced to powders and then mixed with the proper quantity of spirits in a jar. The jar is placed near the fire or in a hot bed of sand or in hot water and the contents agitated by shaking and stirring until they form a liquid. These fluids can be afterwards thickened with gum or resin or thin used with spirits of wine. Strain before using

Transparent Varnish.—Take 4 ozs. gum, and put in into a jar and simmer on oven. Let it go cold, crush it up, then put it into 1 pint methylated spirit with 2 ozs. gum sandral. Apply it warm. This is very suitable for paper.

Shellac Varnish.—Shellac varnish would do for cheap work. Mix 3 lbs. of shellac to a gallon of turpentine.

Polishing.—French polish. A good French polish suitable for the Indian climate can be made with the following ingredients:—

Dissolve in methylated spirit in 3 gallons Shellac, 3 lbs. bib Olibianim (isesa) ½ lb., gambogo ½ lbs., copal or sandral, ½ lb.

Gum Benzoine (Lobana) ½ lb.

The gums are crushed small and added to the spirit and mixture is agitated until the gums are dissolved. A warm bath aids the operation.

The wood to be polished should be first painted with a filler composed of 5 lbs. whiting mixed with ⅓rd of a gallon of methylated spirit and then sand papared. A thin coat of polish should then be applied and sand papered prior to second and third coat. Polishing should be done in dry weather. Copal varnish is the best.

PUTTY.

Linseed oil	.. 12 ozs.	Mix them well together and heat with a wooden mallet. If it becomes hard, heat it before application. 4 lbs. is required for 1,000 s. ft.
Litharge	.. 2½ tolas.	
Spanish whiting	.. 2 lbs.	
Dry white lead	.. 2 ozs.	

To Soften Putty.—Take 3 lbs. of quick lime slake in water, add 1 lb. pearl ash and make the whole of the consistency of paint, apply to both sides of the glass and let it remain 12 hours when the putty will be so softened that the glass may be taken out. This method will remove old paint and varnish.

Glue.—Glue is prepared from waste pieces of skins, horns, hoofs and other animal offal. These are stripped, washed, boiled, strained, melted, reboiled and cast into square cakes which are then dried.

The best glue is transparent, and of a clear Amber colour, free from black or cloudy spots and with little or no smell. It swells considerably when inserted in cold water without dissolving and does not return to its former size when dry. Inferior glue dissolves in cold water.

Preparation of Glue.—It should be broken up into small pieces and soaked in as much cold water as will cover it for about 12 hours. It should then be melted in a double glue pot covered to keep the glue from dust. Care must be taken that the outer vessel is full of water so that the glue shall not burn or be brought to a temperature higher than that of boiling of water.

The glue is allowed to simmer for 2 or 3 hours then gradually melted, so much hot water being added as will make it liquid enough and not to run off a brush in a continuous stream without breaking into drops. Too large a quantity should not be made at a time.

Size.—Size is made from best glue. A pound of glue makes about a gallon of size, size is used with earthy colouring matters to make them adhere to surfaces.

Distempers.—Distempers should be applied in dry weather with a broad stiff brush and after the first coat has thoroughly dried. When lime plaster is very smooth and no primming coat is used, a coating of warm glue should first be applied, if rough a coat of Spanish white or chalk mixed with a solution of glue is employed to render the surface smooth.

Distempers are now manufactured ready for use by different companies. Muraline and Shallemar distempers have a slight advantage over Hall's as they are easier to work and present more even surface. Muraline has the greatest covering power and can be applied to wood with good results. They should be used as recommended by makers.

They grow dark with age.

HINTS FOR PAINTERS.

(1) Cleaning paint.

Paint should be more often swept than scrabbed, when it must be washed. Use a little soap and plenty of water.

(2) Removing old paint.

Caustic alkali made with the strongest solution of soda and boiling water to which is added soap (soft) made into a paste with fresh slaked lime. Lay it thick with trowel and keep wet for two hours, then scrape it off, repeating the process if required. When clean wash off, then apply vinegar to neutralize the alkali. Wash again.

(3) Removing paint smell.

Put 1 or 2 buckets of water in the newly painted room near the paint; with 1 oz. vitrolic acid, added to each of the buckets and in every few days, this will absorb and retain the effluvia from the paint or place a vessel full of lighted charcoal in the room and throw 2 or 3 handfuls of juniper berries or take a handful of good hay and keep in a pail of water near the paint.

(4) Removing paint spots.

Give a thick paste of lime and soda, and in 24 hours after wash it off the wood with clean water.

(5) Removing paint from dress.

After a paint spot has dried, it is difficult to remove. When fresh, having wiped off as much as you can, it can be taken out by repeated application of spirits of wine, rubbed on with flannel.

(6) How to keep paint brushes.

Rinse all brushes and pencils in turpentine after using, then grease with a mixture of tallow and sweet oil. This will prevent them drying hard and stiff. Keep them in a closed tin.

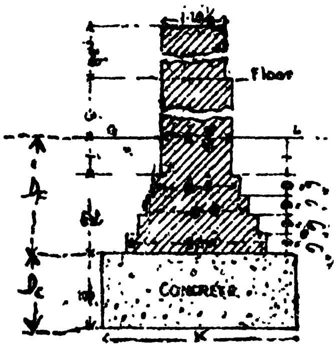
CIVIL ENGINEERING.

Foundations.—Foundations play a very important part in the construction of buildings and bridges. The width of foundations should be calculated accurately for a given load, if neglected most of the buildings begin to show signs of cracks. It is essential to see (1) that the load per square foot should not exceed the values in the table below. (2) That the load under the walls should be the same.

Description of earth.	Load in tons per square foot.
Soft, wet, muddy and marsh clay ..	·25 to 0·33
Ordinary mixed earth of the Punjab and U. P. of Agra and Oudh	0·80
Made ground consolidated and black cotton soil ..	·50
Alluvial earth loams and loamy soil and clay loams ..	·75 to 1·5
Soft chalk	1 to 1½
Hard clay	1·50
Damp clay	1·5 to 2·0
Stony or Rocky	1½ to 3½
Loose sand in shifting river bed ..	2½ to 3
Hard white chalk	2½ to 4
Silted sand of firm character, at depth 25′ below ..	3½ to 4
Solid clay mixed with very fine sand ..	4·00
Very compact, firm, and sandy foundation at a depth not less than 20′ and compact sandy granite ..	6 to 7
Hard Rock	9 tons.

The width of the concrete in foundations should be 6″ more on either side the masonry in foundations to allow ramming of earth when filling is done.

Rule for Finding the Width of Foundations.— Consider a section of wall as shown. It is built on hard clay. The width of the room is 20 ft.



Above plinth area per sq. ft. $=38\times1\frac{7}{8}$

Plinth $=3\times2\frac{1}{16}=6{\cdot}19$ 71·25

Foundation $=1\times2\frac{1}{16}=2{\cdot}06$

Foundation $=\dfrac{4+2\frac{1}{2}}{2}=6{\cdot}50$

Concrete $=2\times x=2x$

Total $=(2x+86)$ s. ft.

Weight $=120\times86$ and $115\times2x$

$=10320+230x$

Weight of roof at 100 lbs per s. ft. $=$

$\dfrac{100\times20}{2}=1000$ lbs.

$\therefore$ Total weight $=(230x+11320)$ lbs.

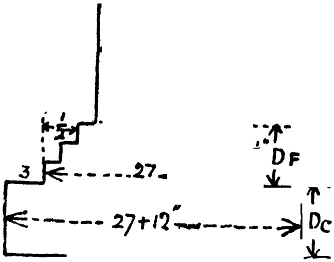
Safe load on hard clay $=1$ ton *i. e.*, 2240 lbs. per sq. ft

∴ Total allowable load on foundation $=2240x$

∴ $2240x=230x+11320$

$x=5\cdot 6$ ft.

In practice for a safe load of one ton per s. ft.



Let T = thickness of wall.

D_f = depth of footings.

D_c = depth of concrete.

Width of foundations $=2T+12''$

$D_f=\frac{2}{3}T$ and $D_c=\frac{1}{3}T$

or allow 6″ concrete for every 10 ft. height of wall. Depth of foundations :—(Rankine's theory).

$$d = \frac{W}{wt}\left(\frac{1-\sin.\phi}{1+\sin.\phi}\right)^2 \text{feet.}$$

Where d = depth of foundations in ft.

w = weight of earth per c. ft.

w = weight of wall per ft. run.

t = thickness of wall in ft.

ϕ = angle of repose.

Foundations on sloping ground :—

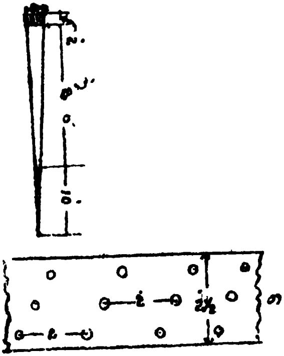
On sloping grounds, the bottom of the trench must be formed into horizontal steps cut according to the slope of the ground to prevent unnecessary depth of foundations at the upper end and consequently a waste of masonry.

Deep foundations in buildings.

In case the foundations are required to take deep on account of bad soil, resort to piles or construct arches on square pillars at short intervals to carry the load.

Foundations in made earth—

Made earth must always be avoided if not, following measures must be adopted to prevent unequal settlement.



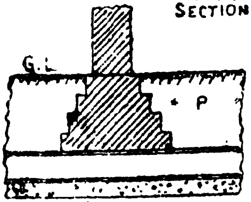
After completing the excavation, painted and iron-shod hard-wood pegs, 4 ft. in length and 6in. in diameter on top, will be driven into the bed of the trench at 2 ft. intervals to a depth of at least 2 ft. They will be spaced as shown in diagram the work proceeding from the centre of the edges.

The pegs are then drawn and the holes thus formed carefully filled up with clean coarse sand.

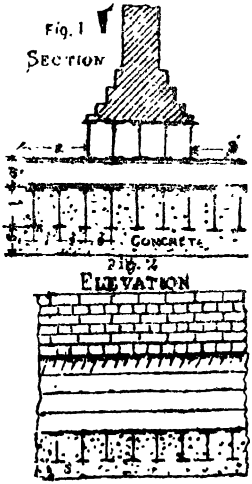
(2) The bottom of the foundation should be well rammed and 6″ to 12″ concrete laid on it. A row of steel joists is laid from one end to the other. Sometimes longitudinal joists are also used (see Sketch above).

The practice of using wood in foundations is objectionable.

FIG 3
SECTION



CONCRETE



CONCRETE

Example :—

The weight of a brick wall together with the superincumbent load is 30 tons per foot run. The width of the lowest footing course of masonry is 7 ft. If the weight allowed on foundations be 2 tons per sq. ft., find the size and length of I Beams required, spaced 18 inches centre to centre.

$$W = \frac{\text{total load}}{\text{allowed load}} = \frac{30}{2} = 15' \text{ (the required length of beam) } w = 7'$$

$$\therefore P = \frac{15 \cdot 7}{[illegible]} = 4 \text{ ft.}$$

$$S = 1\tfrac{1}{2}'$$

Bearing pressure is 2 tons per sq. ft.

,, ,, $2 \times 1\frac{1}{2} = 3$ tons per $1\frac{1}{2}$ sq. ft.

In column of 3 tons, we find 4′ to agree with 12″ girder 31·5 lb. per ft. (*vide* table below).

Table of safe length of projection "P" in feet.

S=12″, and the bearing capacity of ground ranges from 1 to 5 tons.

Bearing capacity in tons per sq. ft.											Depth of beam.	Weight per foot.
1	1¼	1½	2	2¼	2½	3	3½	4	4½	5		
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ins.	lb.
15·2	13·6	12·4	10·8	10·2	9·6	8·8	8·1	7·6	7·2	6·8	24	80·00
14·0	12·5	11·4	9·9	9·3	8·8	8·1	7·5	7·0	6·6	6·2	20	80
12·3	11·2	10·2	8·3	8·3	7·9	7·2	6·7	6·2	5·9	5·6	20	65
10·9	9·7	8·9	7·7	7·3	6·9	6·3	5·8	5·4	5·1	4·9	18	55
11·9	10·6	9·7	8·4	7·9	7·5	6·9	6·4	5·9	5·6	5·3	15	80
10·4	9·3	8·5	7·4	6·9	6·6	6·6	5·6	5·2	4·9	4·7	15	60
8·9	7·9	7·2	6·3	5·9	5·6	5·1	4·7	4·4	4·2	4·0	15	42
7·7	6·9	6·3	5·5	5·1	4·9	4·5	4·1	3·9	3·6	3·5	12	40
6·9	6·2	5·6	4·9	4·6	4·4	4·0	3·7	3·5	3·3	3·1	12	31·5
5·7	5·1	4·7	4·0	3·8	3·6	3·3	3·1	2·9	2·7	2·6	10	25
5·0	4·5	4·1	3·6	3·3	3·2	2·9	2·7	2·5	2·4	2·2	9	21
4·4	3·9	3·5	3·1	2·9	2·7	2·5	2·3	2·2	2·1	1·9	8	18
3·7	3·3	3·0	2·6	2·5	2·3	2·1	2·0	1·9	1·8	1·7	7	15
3·1	2·8	2·5	2·2	2·1	2·0	1·8	1·7	1·6	1·5	1·4	6	12·25
2·5	2·3	2·1	1·8	1·7	1·6	1·5	1·4	1·3	1·2	1·1	5	9·75
2·0	1·8	1·6	1·4	1·3	1·2	1·1	1·1	1·0	0·9	·9	4	7·50

Very deep foundations :—

The foundations for bridges are generally very deep. The nature of soil is examined by means of boring up to stratum of firm soil and then pits are sunk and the foundations laid.

The foundation in running water is established by means of caisson or coffer dams, which is merely a strong box without a lid.

Safe Strength of Masonry.

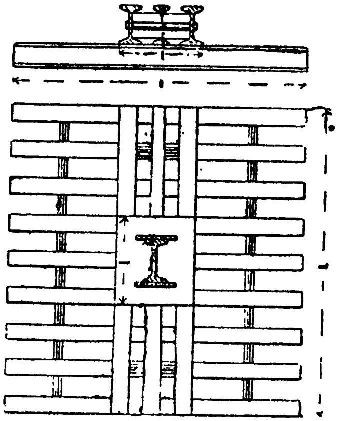
Burnt brick in cement	10 tons per sq. ft.
1st class brickwall in Lime mortar	5 tons per sq. ft.
3rd class brickwall in mud mortar	3 tons per sq. ft.
Lime concrete	5 tons per sq. ft.

Beam Grillages for Stanchions.—For stanchions carrying heavy loads, the necessity for deep excavations and large masses of masonry in foundations may be considerably reduced by the adoption of suitable grillages, combined with stanchion bases, carefully designed to transmit the load.

These are generally obtained by placing on a layer of concrete, one, two, or three tiers of 1 beam, according to the load to be distributed, and the bearing capacity of the ground. The beams in each tier should be kept sufficiently far apart to allow of the space being thoroughly filled with concrete. Cast iron separators, with through bolts, are generally employed to effect this. In cases where two or three tiers are found necessary, they should be efficiently secured to each other, and the stanchion base to the whole.

The following diagram illustrates a grillage, consisting of two tiers of beams :—

DIAGRAM OF GRILLAGES.



The overall dimensions of the lowest tier are determined by the bearing capacity of the ground, and to find the section of beams required in any tier :—

Let W = total load in tons supported by the stanchion

n = number of beams forming the tier

w = load in tons supported by one beam $=\frac{W}{n}$.

L = length in feet of each beam.

l = length in feet, at central portion of beam, on which the load above it is distributed.

M = maximum bending moment in foot tons, in one beam (this occurs at the centre of length L).

then $M=\left(\frac{w}{2}\times\frac{L}{4}\right)-\left(\frac{w}{2}\times\frac{l}{4}\right)=\frac{w}{8}(L-l)$.

The above bending moment is equivalent to that produced in a beam supported at both ends, and carrying a distributed load " w " over a span $= L - l$. Therefore, on reference to this span in the table of safe loads, the size of beam to carry the load w may be obtained direct.

WALLS.

Rule for the thickness of walls in buildings (Engineer-in-chief M. E. S. Circular).

Walls in one storey should not be higher than—

120′ for cement mortar.
60′ for lime mortar.
20′ for mud mortar.

If N = minimum thickness of wall expressed in number of 9″ bricks *i.e.*, if N = 1 the thickness = 9″.

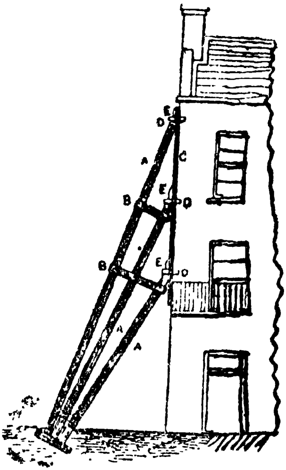
Quarters and Barracks.

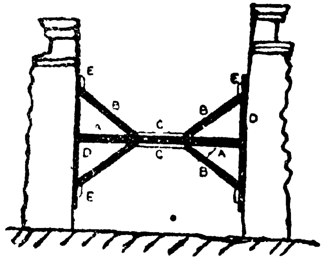
	1-3 Cement mortar.	Lime mortar.	Mud mortar.
	n =	n =	n =
Walls with cross walls not further apart than 45′	$\frac{1}{2} + \frac{H}{40}$	$1 + \frac{H}{40}$	$1\frac{1}{2} + \frac{H}{40}$
Walls, length between cross walls unlimited	$\frac{1}{2} + \frac{H}{40}$	$1 + \frac{H}{40}$	$1\frac{1}{4} + \frac{H}{40}$
Minimum thickness for any storey height H ft.	$\frac{H}{15}$	$\frac{H}{12}$	$\frac{H}{10}$
Workshops, large stores, etc.			
Walls with cross walls not further apart than 45′ ground level thickness.	$\frac{1}{2} + \frac{H}{40}$	$1 + \frac{H}{40}$	$1\frac{1}{4} + \frac{H}{20}$
Walls, length between cross walls unlimited, ground level thickness.	$\frac{1}{2} + \frac{H}{40}$	$1 + \frac{H}{40}$	$1\frac{1}{4} + \frac{H}{40}$
In both above cases the top 10′ wall ..	$1\frac{1}{2}$	$2\frac{1}{4}$	3
	Cement	Lime.	Mud.
Minimum thickness for any storey height H-ft.	$\frac{H}{15}$	$\frac{H}{12}$	$\frac{H}{10}$

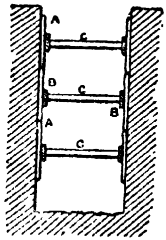
Basement and foundation walls should be $4\frac{1}{2}$″ thicker than the walls at ground level.

SHORING BUILDINGS.

Raking and flying shores :—







The above figures show the usual method of shoring dangerous structures.

Fig. (1) represents a "Raking shore" and Fig. (2) a "Flying shore," for shoring two houses.

B B are the braces in Fig. (1) and struts in Fig. (2). The braces should be 1″×9″ in Fig. (1) and nailed to the sides of raking shores to keep them rigid. C is a plank 9″×3″ placed against wall. D D D are the timber needles 6″×4″ passing through the plant and leaving about 5″ projection outside and let the same distance into the wall.

E E E are the cleats, spiked to the plank on the upper side of each needle. A A A are the shores. Sizes from 6″×6″ to 12″×6″ according to the size of building, fixed to the Block G buried in the ground. The longest shore is called the top raker. The block G buried in the ground is called the "sole piece" and must be bedded at a little less than right angles with the inner surface of the rakes so that as the latter are driven up, they tighten on the sole pieces.

A system on 3 raking shores as shown above is suitable for walls upto 40 ft. high. The raking shores should be about 15 ft. apart and incline at an angle of 60 to 75 degrees.

The following are approximate scantlings :—

***Raking shores*—**

Walls upto 20 ft. height	..4″×4″ or 5″×5″
Walls upto 30 ft. height	..6″×6″ or 9″×4½″
Walls upto 40 ft. height	..8″×8″ or 6″×12″
Walls upto 50 ft. and upward	..9″×9″ or 12″×9″

***Flying shores*—**

Span not more than 20 ft.	..Span upto 30 ft.
Principal shore A 6″×4″	..6″×6″ or 9″×9″
Struts B 4″× 4″	..6″×4″ or 9″×6″

Chimneys—

Sizes of flues.—A section 9″×9″ is sufficient to carry off the smoke from very small gates ; a flue 9″×14″ from ordinary domestic fire places and a flue 14″×14″ from large kitchen ranges.

Chimney flues are usually plastered internally with a mixture of 1 part lime and 3 of cow-dung (design see part II).

Practical points in tall chimney construction.—(1) The concrete and masonry of foundations should be allowed to settle before the shaft is built.

(2) Cement mortar should be used in foundations, but for the shaft best lime mortar well ground is preferable to cement as being less rigid, the cap may be in cement and rendered ; cement is liable to lose its power when exposed to great heat.

(3) The bond usually adopted is one course headers to 4 of stretchers.

(4) All joints should be well filled and carefully pointed.

(5) Not more than 3 ft. of masonry to be carried up in one day.

(6) Heavy caps should be avoided.

(7) An arched and invert opening should be left in the chimney at or nearer the ground level to be bricked afterwards with firebricks 9″ thick so as to allow easy access to the interior.

(8) Stair cases:—General rule (Molesworth).

R=Rise in inches.
T=Tread in inches.

$$R=\frac{66}{T} \text{ or } R=18-T$$

R not to exceed 7″ nor less than 5½″
T not to exceed 12″ nor less than 9″

} Standard—A 9″ tread should have a 7″ riser.

***Types of stairs*—**

1. Straight flight stair unbroken or with intermediate landing.
2. Rectangular open well stair.
3. Dog legged stair.
4. Circular stair for design see part II drawings.

In ordinary wooden stairs the treads are from 1 to 1½ inches thick ; risers ⅞″ to 1¼″, strings 1½″ to 2″, balusters 1½″ to 2 square and newels 4″ to 5″ square and the other dimensions, of course, vary according to the circumstances, etc

VALUATION OF BUILDINGS.

To find years purchase allowing for redemption of capital at a different rate of interest.

Let X = required years purchase.
t = future life of property.
Y = Annual premium for sinking fund to produce £1 at the end of t years.
I = Interest allowed per years purchase.
r = interest allowed per years redemption of capital.
∴ £1 of nett income must allow for—
(*i*) Interest for 1 year on x at 1 per cent.
(*ii*) Y for $x = xy$
(*iii*) Interest on xy for 1 year at r per cent. as y has to be invested at beginning of first year.

$$\therefore \; 1 = \frac{I}{100}x + xy + \frac{r}{100}xy$$

$$= x\left\{\frac{I}{100} + y\left(1 + \frac{r}{100}\right)\right\}$$

$$\therefore \; x = \frac{1}{\frac{I}{100} + y\left(1 + \frac{r}{100}\right)}$$

Example $t = 75$ *years*
$I = 6\ \%$
$r = 3\frac{1}{2}\ \%$

Y (for 75 years) see table III (Hurst, 15th edition). Pocket Book page 432 The annual or sinking fund that with a compound interest will amount to £1 at the end of a term of 75 years ∴ Y = ·0029

Then from formulae above.

$$x = \frac{1}{\cdot06 + \cdot0029\ (1\cdot035)}$$

$$= \frac{1}{\cdot06 + \cdot003}$$

$$= \frac{1}{1\cdot063.}$$

$$= 15\cdot9$$

The above value of Y can be found by the following formula in case the tables are not available.

$S = \dfrac{r}{R^n - 1}$ where n = number of years
$R = (1 + r)$ or £ 1 increased by interest for a year.

S = an annual sinking fund which will amount to £1 in any number of years at compound interest.

r = rate of interest on £1 for one year.

Example of valuation of Buildings.

Book or estimated value of building ..	..Rs. 11,000			
Age of Building 1895—1920 ..	..years 25			
Future life 100—25	..years 75			
Gross annual rent at Rs. 100×12 ..	..Rs. 1,200			
Deduct—	Rs.	a.	p.	
Rates and taxes :—House tax	33	9	7	
Vacancies $\frac{1}{2}$ month p. a.	50	0	0	
Repairs at $2\frac{1}{2}$ on $\frac{9}{10}$th of 11,000	247	8	0	
Insurance	*nil*			
	331	1	7	say 331/-
Net income ..	869	0	0	

Years purchase for 75 years at 6 per cent. allowing for redemption of capital at $3\frac{1}{2}$ per cent.=15·9

Value of property =869×15·9=Rs.	13,817	0	0
Deduct value of repairs immediately necessary	1,620	0	0
Total ..	12,197	0	0

SCAFFOLDING KNOTS.

Fig. 1 sheep-shank, for shortening a rope when the ends are inaccessible.

Fig. 2 Half hitch.

Fig. 3 square or reef knot used for joining two ropes of same size. It is easily upset and undone.

Fig. 4 overhand or thumb knot, used to prevent a rope running through the sheave of a block.

Fig 5, Carrick Bend, for fastening the four guys to a derrick.

Fig. 6 double Bowline. Fig. 7 clove hitch.

This is most useful of all the knots used in scaffoldings. Fig. 8, Running knot. Fig. 9, Draw knot, Fig. 10, same as Fig. 3, Fig. 11, Single Bowline knot, for making a loop that will not slip. Fig. 12, Timber hitch, the greater the strain the greater it will hold.

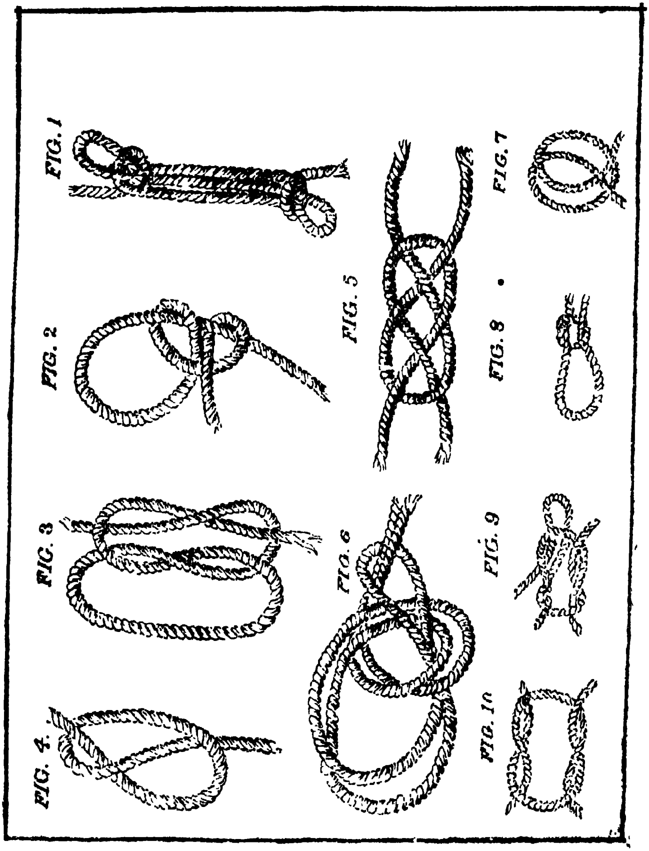
Figs. 13 and 14 same as Fig. 7, *i.e.* Clove hitch.

Fig. 15, Men's harness. Fig. 16, Running Bowline and Figs. 19 and 20 Cat's paw, an endless loop, used when great power is required.

Figs. 22 and 23, common sheet bend, it is the same as reef knot, but better one.

Fig. 24, outside clench. Fig. 25, inside clench. Fig. 26, cat's paw Figs. 27 and 29 woolding or packing still hitch. Fig. 28, stopper hitch.

Fig. 30, Hawser bend.


FIG. 1
FIG. 2
FIG. 3
FIG. 4.
FIG. 5
FIG. 6
FIG. 7
FIG. 8
FIG. 9
FIG. 10

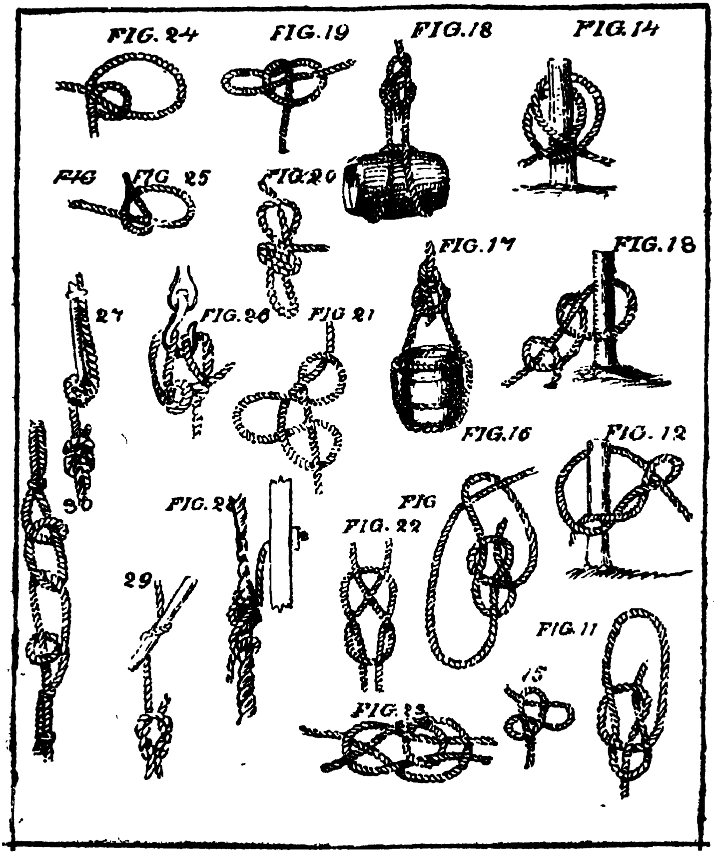

FIG. 24
FIG. 19
FIG. 18
FIG. 14
FIG
FIG 25
FIG. 20
FIG. 17
FIG. 18
27
FIG. 26
FIG 21
FIG. 16
FIG. 12
30
FIG. 28
FIG
FIG. 22
29
FIG. 11
15
FIG. 23

TABLE OF USEFUL MEMORANDA, AFFECTING THE PLANNING OF BUILDINGS.

Extract from Hursts, etc., Marks and Spons.

	Accommodation.	Dimensions.
Altar ..		3′-0″ to 9′-0″ long × 2′-0″ to 2′-6″ wide.
Art scholar (drawing class-room	30′ super	
Ball Room ..	16′-0″ super (min.)	•
Bath, Plunge (unclosed)	Max. 6′-3″ × 2-′8″ over all.	
Bath Plunge (water-supply) ..	40 to 50 gallons.	
Bath Shower (water-supply)..	3 to 6 gallons.	
Baths (Boarding School) ..	8 per cent. of boaders	
Baths Swimming ..	....	100′×35′ and 6′ to 7′ deep at deep end and 3′ 6″ at shallow end. Copper rail all round 1½″ diam.
Bed in Hospital ward .		6-′3″×3′-4″.
Bed in Hospital (spacing along wall between beds).		8′-8″
Bed in Hospital ward (space across centre gangway between beds).		10′-6″ (min.)
Bed in House, Double .		6′-6″×4′-6″ (Min.)
Bed in House, Single .		5′-6″×2′-6″ to 6′-6″ × 2′-3″
Bed in (Infant's cot.) .		4′×2′ to 4′-6″×2′-6″
Bed room (Dormitory) .	360′ cube per head	
Bed room (schools) .	65 sq. ft. or 800 c. ft. per head.	
Bed room (Hotel) .		12′×8′
Benet, Cabinet making (schools)		6′×2′
Benet, carpenters		3′-4″×1′-4″ to 7′-0″×2′-0″
Bicycle House		6′-3″×2′-0″ (min.)
Billiard Table		12′-0″×6′-0″ to 6′×3′
Billiard Room		24′×18′ (if lounges required extra space should be provided).

Extract from Hursts, etc., Marks, and Spons—continued.

	Accommodation.	Dimensions.
Bowling, green ..	..	120′×120′
Boiler (Cornish or Lancashire)	..	12′ long×4′dia. to 30′ long and 7′ diam.
Cattle sheds—		
Sheep or pig ..	10 sq. ft. ..	
(Cornish and Lancashire bullock) ..	40 to 60 sq. ft.	
Cell, Prison Association ..	..	14′×14′
Cell, Solitary ..	..	13′×7′ and 600 to 800 c. ft.
Corridor (Schools) ..	..	8′ to 12′ wide.
Countor ..		2′-6″ to 4′ wide.
Cow house, dunging passage ..	..	4′-6″ wide.
Cow house stall, double ..	..	7′×7′
Cow house, single ..	..	4′-6″ ×6′ to 7′.
Cow shed per beast ..	40 to 60 sq. ft.	
Coach houses ..	..	18′ deep×10′ high, door 8, wide.
Cubicle for nurse ..	..	13′×8′-6″
Cubicle for school ..	..	8′×8′
Dining Hall per scholar ..	10 sq. ft.	
Dining Table per diner ..	2′ width (min.)	
Dining Table (social) ..	..	5′×3′-3″ to 12′×4′-9″ and more.
Dressing box (swerving) ..	..	3′×3′ to 4′-6″×4′-0″
Dressing Table (area of top) ..	..	2′-9″×1′-6″ to 4′-6″×2′
Engine, Electric lighting (bed plate size).	.	4′×1′-6″ to 6′-8″×2′
Engine and Dynamo ..	.	5′-6″×2′-3″ to 25′×3′-3″
Engine (gas or oil) ..	.	4′-6″×2′-7″ to 14′-3″×13′-6″
Engine house, Fire Brigade ..	.	40′×28′-3″
Hospital ward, per patient .	1,800 to 2,000 c. ft. 144′ to 156′ sq. ft.	
Hospital ward (water-supply).	27 gallons per day.	
Ice (storage room per cwt.) ..	6′-0 cube.	
Inclined planes ..	1 in 10	
(Max. gradient in London theatre)		
Kitchen table .	..	4′-6″×3′-0″
Laboratory	30 sq. ft. per scholar.	

Extract from Hursts, etc., Marks, and Spons—continued.

	Accommodation.	Dimensions.
Lavatory Basins (circular)		10″ to 1′-10″ diam.
Lavatory Basins (oval) ..		1′-2″×12″ to 2′-3″×1′-9″
Lecture room (Schools) ..	14 sq. ft. for scholar (min.)	
Library (Magazine room per head). ..	2′×1′-3″	
Library News room per head ..	2′-6″×1′	
Library Book case in house ..		4′-0″×10″
Library Table in Magazine room. ..		2′ wide (min.)
Library Table News room ..		2′-6″ wide (min.)
Lift Cage for—		
Books ..		9″×9″ to 1′×1′
Carriage and Motor Cars ..		16′-0″×8′-0″
Cellar ..		2′-6″×2′-0″ (min.)
Coal ..		2′×2′
Dinner, etc. ..		1′×10″ (min.).
Hospital patient on bed ..		7′-6″×4′-6″
Luggage ..		2′-6″×2′-6″
Passenger ..		2′-6″×3′-0″
Warehouse ..		2′×1′-6″ to 9′×5′
Motor Carriage House ..		from 22′×12′ upward.
Poultry House and Room (for 12 fowls). ..		4′×4′
Poultry House and Room (for 50 fowls) ..		8′×6′
Range, cottage ..		2′ to 3′-2″ wide.
Range, Hotel ..		6′ to 15′ wide.
Range, Kitchen ..		3′-6″ to 7′ wide ×1 8″ to 1′-10″ deep.
Seating accommodation—		
Church (free sitting) ..	1′-8″×2′-3″ deep per head.	
Church (free child) ..	1′-2″×2′-3″ deep	
Stairs churches, Lecture room not exceeding 200 men ..		3′-6″ wide.
200 to 400 ..		4′-6″
per 100 additional ..		6″ increase in width.
Max. ..		9′ wide.
Stores gas cooking ..		1′-2″×1′-3″ to 2′-3″×2′-4″
Stores grilling ..		2′ to 4′ wide by 2′ deep.

Extract from Hursts, etc., Marks and Spons—concld.

	Accommodation.	Dimensions.
Stores ordinary ..		1′-3″ × 1′-3″ to 3′-2″ × 4′-3″
Table Restaurant (circular top). ..		1′-8″ to 2′-4″ dia.
Table Restaurant straight ..		3′ × 1′-6″ to 7′ × 4′
Tanks, hot water (cylindrical)		1′-3″ diam. × 2′-6″ high
Urinal accommodation (school)	10 ft. per 100 boys.	to 1′-8″ diam. × 4′ high.
Urinal Compartments ..		1′-8″ × 11″ to 2′ × 1′-4″
Water closet (Boarding School)	4 per 30 scholars.	
Water closet seat ..	3′-6″ wide.	
Workshop per scholar in schools.	35 sq. ft.	
Tennis Court Lawn ..		
Single ..	..	78′ × 27′
Double ..	..	78′ × 36′
	allow 12′ each end and 6 ft. each side.	
Croquet Lawn ..		105′ × 84′
Coal Store ..		For every ton of coal allow 45 c. ft.

Table of Safe Diameters of Deodar and Salwood Ballas.

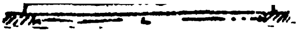
L. Spans.	DEODAR BALLAS, $d^3 = \frac{WL}{550}$.						SALWOOD BALLAS, $d^3 = \frac{WL}{950}$.						L. Spans.
	80 lbs. roof.			120 lbs. roof.			80 lbs. roof.			120 lbs. roof.			
	Spacings from C to C.						Spacings from C to C.						
	12″	18″	24″	12″	18″	24″	12″	18″	24″	12″	18″	24″	
″	″	″	″	″	″	″	″	″	″	″	″	″	″
3	2¼	3	3¼	3	3¼	3½	2¼	2½	3	2½	3	3¼	3
3½	2¾	3	3½	3	3½	4	2½	2¾	3	2¾	3	3½	3½
4	3	3½	3¾	3½	4	4½	2½	3	3¼	3	3¼	3¾	4
4½	3¼	3¾	4¼	3¾	4¼	4¾	2¾	3¼	3½	3¼	3¾	4	4½
5	3½	4	4½	4	4½	5	3	3½	3¾	3½	4	4¼	5
5½	3¾	4¼	4¾	4¼	5	5½	3¼	3¾	4	3¾	4¼	4½	5½
6	4	4½	5	4½	5¼	5¾	3¼	3¾	4¼	3¾	4½	4¾	6
6½	4¼	4¾	5¼	4¾	5½	6	3½	4	4½	4	4½	5	6½
7	4½	5	5½	5	5¾	6½	3¾	4¼	4¾	4¼	5	5¼	7
7½	4½	5¼	5¾	5¼	6	6½	4	4½	5	4½	5	5½	7½
8	4¾	5½	6	5½	6½	7	4	4½	5	4½	5¼	5¾	8
8½	5	6	6¼	6	6¾	7½	4¼	4¾	5¼	4¾	5½	6	8½
9	5¼	6	6½	6	6¾	7½	4½	5	5½	5	5¾	6¼	9
9½	5½	6¼	6¾	6¼	7	7¾	4½	5¼	5¾	5¼	6	6½	9½
10	5½	6½	7	6½	7½	8	4¾	5½	6	5½	6¼	6¾	10
10½	5¾	6½	7¼	6½	7½	8½	5	5½	6	5½	6½	7	10½
11	6	6¾	7½	6¾	7¾	8½	5	5¾	6¼	5¾	6½	7¼	11
11½	6	7	7¾	7	8	8¾	5¼	6	6½	6	6¾	7½	11½
12	6¼	7¼	8	7¼	8¼	9	5¼	6	6¾	6	7	7½	12

Table of Scantlings of Teak, Sal or Keekar, Karees or Burgas placed 9″ apart centre to centre.

L = Span.

Span L.	Distributed load in lbs., per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2	1½	2	1½	2
2½	1½	2	1½	2	1½	2	1½	2¼	1½	2¼
3	1½	2	1½	2¼	1½	2¼	1¾	2½	1¾	2¾
3½	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
4	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
4½	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
5	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
5½	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2¼	4
6	2¼	3½	2½	3¾	2½	3¾	2½	4	2¾	4¼
6½	2½	3¾	2½	4	2½	4	2¾	4¼	3	4½
7	2½	4	2½	4	2¾	4¼	3	4½	3	4¾
7½	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
8	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
8½	3	4½	3	4¾	3¼	5	3½	5¼	3½	5½
9	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	5¾
9½	3	4¾	3½	5¼	3½	5¼	3¾	5¾	3¾	6
10	3¼	5	3½	5¼	3½	5½	3¾	6	4	6½
Placed 1′ apart centre to centre.										
2	1½	2	1½	2	1¼	2	1½	2	1½	2
2½	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
3	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾
3½	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
4	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
4½	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
5	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2½	4
5½	2¼	3½	2½	3¾	2½	3¾	2½	4	2¾	4¼
6	2½	3¾	2½	4	2½	4	2¾	4¼	2¾	4¾
6½	2½	4	2¾	4¼	2¾	4¼	3	4½	3¼	5
7	2¾	4¼	2¾	4½	3	4½	3	4¾	3½	5¼
7½	3	4½	3	4¾	3	4¾	3¼	5	3½	5½
8	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
8½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
9	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
9½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
10	3½	5½	3¾	5¾	3¾	6	4	6¼	4½	6¾

Table of Scantlings of Teak, Sal or Keekar, Karees or Burghas placed 18″, apart from centre to centre.



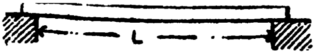
L=Span.

Span L.	Distributed load in lb., per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	d	b	d	b	d	b	d	b	d
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2	1½	2¼	1½	2¼
2½	1½	2¼	1½	2¼	1¾	2½	1¾	2½	1¾	2¾
3	1¾	2½	1¾	2¾	1¾	2¾	2	3	2	3
3½	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
4	2	3	2¼	3¼	2¼	3½	2¼	3½	2½	3¾
4½	2¼	3¼	2¼	3½	2½	3¾	2½	3¾	2¾	4¼
5	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
5½	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
6	2½	4	2¾	4¼	3	4½	3	4¾	3½	5¼
6½	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5½
7	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
7½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
8	3¼	5	3½	5¼	3½	5½	3¾	6	4	6¼
8½	3½	5¼	3½	5½	3¾	5¾	4	6¼	4¼	6¾
9	3½	5½	3¾	5¾	3¾	6	4¼	6½	4½	7
9½	3¾	5¾	3¾	6	4	6¼	4¼	6¾	4¾	7¼
10	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½

Placed 2′ Apart centre to centre.

Span L.	80 lb. b	80 lb. d	100 lb. b	100 lb. d	120 lb. b	120 lb. d	150 lb. b	150 lb. d	200 lb. b	200 lb. d
2	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
2½	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
3	1¾	2¾	1¾	2¾	2	3	2	3	2¼	3¼
3½	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
4	2¼	3¼	2¼	3½	2½	3¾	2½	3¾	2½	4
4½	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
5	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
5½	2¾	4¼	2¾	4¼	3	4½	3	4¾	3½	5¼
6	3	4½	3	4¾	3	4¾	3½	5¼	3½	5½
6½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	5¾
7	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
7½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
8	3½	5½	3¾	5¾	3¾	6	4	6¼	4¼	6¾
8½	3¾	5¾	3¾	6	4	6¼	4¼	6½	4½	7
9	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½
9½	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾
10	4¼	6½	4¼	6¾	4½	7	4¾	7½	5	8

Table of Scantlings of Sheesham or Ber Karees or Burghas placed 9″ apart centre to centre.



L = Span.

Span L.	Distributed load in lb., per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2	1½	2	1½	2
2½	1½	2	1½	2	1½	2	1½	2¼	1¾	2½
3	1½	2¼	1½	2¼	1¾	2½	1¾	2½	1¾	2¾
3½	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾	2	3
4	1¾	2¾	1¾	2¾	2	3	2	3	2¼	3¼
4½	2	3	2	3	2¼	3¼	2¼	3½	2¼	3¾
5	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾	2½	4
5½	2¼	3½	2¼	3½	2½	3¾	2½	4	2¾	4¼
6	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
6½	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
7	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
7½	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
8	3	4½	3	4¾	3¼	5	3½	5¼	3½	5½
8½	3	4¾	3¼	5	3¼	5	3½	5½	3¾	5¾
9	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
9½	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
10	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½

Placed 1′ apart centre to centre.

Span L.	80 lb. *b*	80 lb. *d*	100 lb. *b*	100 lb. *d*	120 lb. *b*	120 lb. *d*	150 lb. *b*	150 lb. *d*	200 lb. *b*	200 lb. *d*
2	1½	2	1½	2	1½	2	1½	2	1½	2¼
2½	1½	2	1½	2¼	1½	2¼	1¾	2½	1¾	2½
3	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
3½	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
4	1¾	2¾	2	3	2¼	3¼	2¼	3¼	2¼	3½
4½	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾	2½	4
5	2¼	3½	2¼	3½	2½	3¾	2½	4	2½	4¼
5½	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
6	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
6½	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
7	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5½
7½	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
8	3	4¾	3¼	5	3½	5¼	3¾	5½	3¾	6
8½	3¼	5	3½	5¼	3¼	5½	3¾	5¾	4	6¼
9	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
9½	3½	5½	3¾	5¾	3¾	6	4	6¼	4¼	6¾
10	3½	5½	3¾	6	4	6¼	4¼	6½	4½	7

Table of Scantlings of Sheesham or Ber Karees or Burghas placed 18″ *apart centre to centre.*



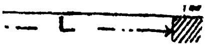
L = Span.

Span L.	Distributed load in lb. per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
2½	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾
3	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
3½	2	3	2	3	2¼	3¼	2¼	3¼	2¼	3½
4	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾	2½	4
4½	2¼	3½	2½	3¾	2½	3¾	2½	4	2¾	4¼
5	2½	3¾	2½	4	2¾	4	2¾	4¼	3	4¾
5½	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
6	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
6½	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
7	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
7½	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
8	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
8½	3½	5½	3¾	5¾	3¾	6	4¼	6½	4¼	6¾
9	3¾	5¾	3¾	6	4	6¼	4¼	6¾	4¾	7¼
9½	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½
10	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾

Placed 2′ apart centre to centre.

Span L.	80 lb. *b*	80 lb. *d*	100 lb. *b*	100 lb. *d*	120 lb. *b*	120 lb. *d*	150 lb. *b*	150 lb. *d*	200 lb. *b*	200 lb. *d*
2	1½	2	1½	2¼	1½	2¼	1¾	2½	1¾	2½
2½	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾	2	3
3	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
3½	2	3	2¼	3¼	2¼	3½	2¼	3½	2½	3¾
4	2¼	3½	2¼	3½	2½	3¾	2½	4	2¾	4¼
4½	2½	3¾	2½	4	2½	4	2¾	4¼	3	4½
5	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
5½	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
6	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
6½	3	4¾	3¼	5	3½	5¼	3¾	5¾	3¾	6
7	3¼	5	3½	5½	3½	5½	3¾	6	4¼	6½
7½	3½	5¼	3¾	5¾	3¾	6	4	6¼	4¼	6¾
8	3½	5½	3¾	6	4	6¼	4¼	6½	4½	7
8½	3¾	6	4	6¼	4¼	6½	4¼	6¾	4¾	7¼
9	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾
9½	4¼	6½	4¼	6¾	4½	7	4¾	7½	5	8
10	4½	6¾	4½	7	4¾	7¼	5	7¾	5¼	8¼

Table of Scantlings of Mango, Karees or Burghas placed 9″ apart Centre to Centre.



L = Span.

Span L.	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2	1½	2	1½	2
2½	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
3	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾
3½	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
4	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
4½	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
5	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2½	4
5½	2¼	3½	2½	3¾	2½	3¾	2½	4	2¾	4¼
6	2½	3¾	2½	4	2½	4	2¾	4¼	3	4¾
6½	2½	4	2¾	4¼	2¾	4¼	3	4½	3¼	5
7	2¾	4¼	3	4½	3	4½	3	4¾	3½	5¼
7½	3	4½	3	4¾	3	4¾	3¼	5	3½	5½
8	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
8½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
9	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
9½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
10	3½	5½	3¼	5¾	3¾	6	4	6¼	4¼	6¾
Placed 1′ apart centre to centre.										
2	1½	2	1½	2	1½	2	1½	2	1½	2¼
2½	1½	2¼	1½	2¼	1½	2¼	1¾	2½	1¾	2¾
3	1¾	2½	1¾	2½	1¾	2¾	1¾	2¾	2	3
3½	1¾	2¾	1¾	2¾	2	3	2¼	3¼	2¼	3¼
4	2	3	2¼	3¼	2¼	3¼	2½	3½	2½	3¾
4½	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2½	4
5	2¼	3½	2½	3¾	2½	3¾	2½	4	2¾	4¼
5½	2½	3¾	2½	4	2¾	4¼	2¾	4¼	3	4¾
6	2½	4	2¾	4¼	3	4½	3	4¾	3¼	5
6½	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
7	3	4½	3	4¾	3¼	5	3½	5¼	3½	5½
7½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
8	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
8½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
9	3½	5½	3¾	5¾	3¾	6	4	6¼	4¼	6¾
9½	3½	5½	3¾	6	4	6¼	4¼	6½	4½	7
10	3¾	5¾	4	6¼	4¼	6½	4¼	6¾	4¾	7¼

Table of Scantlings of Mango Karees or Burghas placed 18″ *apart Centre to Centre.*

L=Span.

Span L.	Distributed load in lb. per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
2½	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
3	1¾	2¾	1¾	2¾	2	3	2	3	2¼	3¼
3½	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
4	2¼	3¼	2¼	3½	2½	3¾	2½	3¾	2½	4
4½	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
5	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
5½	2¾	4¼	2¾	4¼	3	4½	3	4¾	3½	5¼
6	3	4½	3	4¾	3	4¾	3½	5¼	3½	5½
6½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	5¾
7	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
7½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
8	3½	5½	3¾	5¾	3¾	6	4	6¼	4¼	6¾
8½	3¾	5¾	3¾	6	4	6¼	4¼	6½	4½	7
9	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½
9½	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾
10	4¼	6½	4¼	6¾	4½	7	4¾	7½	5	8

Placed 2′ apart centre to centre.

Span L.	80 lb. *b*	80 lb. *d*	100 lb. *b*	100 lb. *d*	120 lb. *b*	120 lb. *d*	150 lb. *b*	150 lb. *d*	200 lb. *b*	200 lb. *d*
2	1½	2¼	1½	2¼	1½	2¼	1¾	2½	1¾	2¾
2½	1¾	2½	1¾	2¾	1¾	2¾	2	3	2	3¼
3	1¾	2¾	2	3	2¼	3¼	2¼	3½	2¼	3½
3½	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2½	4
4	2¼	3½	2½	3¾	2½	4	2½	4	2¾	4½
4½	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
5	2¾	4¼	3	4½	3	4½	3	4¾	3¼	5¼
5½	3	4½	3	4¾	3¼	5	3½	5¼	3½	5½
6	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	6
6½	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
7	3½	5¼	3½	5½	3¾	5¾	4	6¼	4¼	6½
7½	3½	5½	3¾	6	4	6¼	4¼	6½	4½	7
8	3¾	5¾	4	6¼	4¼	6½	4¼	6¾	4¾	7¼
8½	3¾	6	4¼	6½	4¼	6¾	4½	7	5	7¾
9	4	6¼	4¼	6¾	4½	7	4¾	7½	5	8
9½	4¼	6¾	4½	7	4¾	7¼	5	7¾	5¼	8¼
10	4½	7	4¾	7½	4½	7½	5	8	5½	8½

Table of Scantlings of Deodar, Chil, Kail, Karees or Burghas placed 9′ apart Centre to Centre.

L=Span.

Span L.	Distributed load in lb., per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2	1½	2	1½	2	1½	2¼	1½	2¼
2½	1½	2¼	1¼	2¼	1¾	2½	1¾	2½	1¾	2¾
3	1¾	2½	1¾	2¾	1¾	2¾	2	3	2	3
3½	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
4	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
4½	2¼	3¼	2¼	3½	2½	3¾	2½	4	2¾	4¼
5	2¼	3½	2¼	3¾	2½	4	2¾	4¼	3	4½
5½	2¼	3¾	2½	4	2¾	4¼	3	4½	3	4¾
6	2½	4	2¾	4¼	3	4½	3	4¾	3½	5¼
6½	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5½
7	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
7½	3	4¾	3¼	5	3½	5¼	3¾	5¾	3¾	6
8	3¼	5	3½	5¼	3½	5½	3¾	6	4	6¼
8½	3½	5¼	3½	5½	3¾	5¾	4	6¼	4¼	6¾
9	3½	5½	3¾	5¾	3¾	6	4¼	6½	4½	7
9½	3¾	5¾	3¾	6	4	6¼	4¼	6¾	4¾	7¼
10	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½

Placed 1″ apart centre to centre.

Span L.	80 lb. *b*	80 lb. *d*	100 lb. *b*	100 lb. *d*	120 lb. *b*	120 lb. *d*	150 lb. *b*	150 lb. *d*	200 lb. *b*	200 lb. *d*
2	1½	2	1½	2	1½	2¼	1½	2¼	1¾	2½
2½	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
3	1¾	2¾	1¾	2¾	2	3	2	3	2¼	3¼
3½	2	3	2¼	3¼	2¼	3¼	2¼	3½	2½	3¾
4	2¼	3¼	2¼	3½	2¼	3½	2½	3¾	2½	4
4½	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
5	2½	3¾	2½	4	2¾	4¼	3	4½	3	4¾
5½	2¾	4¼	2¾	4¼	3	4½	3	4¾	3½	5¼
6	3	4½	3	4¾	3	4¾	3½	5¼	3½	5½
6½	3	4¾	3¼	5	3½	5¼	3½	5½	3¾	5¾
7	3¼	5	3½	5¼	3½	5½	3¾	5¾	4	6¼
7½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
8	3½	5½	3¾	5¾	3¾	6	4	6¼	4¼	6¾
8½	3¾	5¾	3¾	6	4	6¼	4¼	6¾	4½	7
9	3¾	6	4	6¼	4¼	6½	4½	7	4¾	7½
9½	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾
10	4½	6½	4¼	6¾	4½	7	4¾	7½	5	8

Table of Scantlings of Deodar, Chil, Kail, Karees or Burghas placed 18″ apart Centre to Centre.

L=Span.

Span L.	Distributed load in lbs. per square foot.									
	80 lb.		100 lb.		120 lb.		150 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	1½	2¼	1½	2¼	1¾	2½	1¾	2½	1¾	2¾
2½	1¾	2½	1¾	2¾	1¾	2¾	2	3	2¼	3¼
3	2	3	2	3	2¼	3¼	2¼	3½	2½	3¾
3½	2¼	3¼	2¼	3½	2½	3¾	2½	3¾	2½	4
4	2¼	3½	2½	3¾	2½	4	2¾	4¼	3	4½
4½	2½	4	2¾	4¼	2¾	4¼	3	4½	3¼	5
5	2¾	4¼	3	4½	3	4¾	3¼	5	3½	5¼
5½	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
6	3	4¾	3½	5¼	3½	5¼	3¾	5¾	3¾	6
6½	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
7	3½	5½	3¾	5¾	3¾	6	4	6½	4¼	6¾
7½	3¾	5¾	3¾	6	4	6¼	4¼	6¾	4¾	7¼
8	3¾	6	4¼	6½	4¼	6¾	4½	7	4¾	7½
8½	4	6¼	4¼	6¾	4½	7	4¾	7¼	5	7¾
9	4¼	6½	4½	7	4¾	7¼	5	7¾	5¼	8¼
9½	4¼	6¾	4¾	7¼	4¾	7½	5	8	5½	8½
10	4½	7	4¾	7½	5	7¾	5¼	8¼	5½	8¾
Placed 2″ apart centre to centre.										
2	1½	2¼	1¾	2½	1¾	2½	1¾	2¾	2	3
2½	1¾	2¾	2	3	2	3	2¼	3¼	2¼	3½
3	2¼	3¼	2¼	3¾	2¼	3½	2½	3¾	2½	4
3½	2¼	3½	2½	3¾	2½	4	2½	4	3	4½
4	2½	4	2½	4	2¾	4¼	3	4½	3	4¾
4½	2¾	4¼	3	4½	3	4¾	3¼	5	3¼	5¼
5	3	4½	3	4¾	3¼	5	3½	5¼	3¾	5¾
5½	3¼	5	3½	5¼	3½	5½	3¾	5¾	3¾	6
6	3½	5¼	3½	5½	3¾	5¾	3¾	6	4¼	6½
6½	3½	5½	3¾	5¾	3¾	6	4¼	6½	4½	7
7	3¾	5¾	4	6¼	4¼	6¼	4¼	6¾	4¾	7¼
7½	4	6¼	4¼	6½	4¼	6¾	4¾	7¼	5	7¾
8	4¼	6½	4¼	6¾	4½	7	4¾	7½	5	8
8½	4¼	6¾	4½	7	4¾	7½	5	7¾	5¼	8½
9	4½	7	4¾	7½	5	7¾	5¼	8¼	5½	8¾
9½	4¾	7¼	5	7¾	5	8	5½	8½	6	9¼
10	4¾	7½	5	8	5½	8½	5½	8¾	6	9½

Table of Scantlings for BEAMS, under different Loads distributed.

Deodar, Chir or Kail 2′ Centre to Centre.

Teak, Sal or Keekar 4′ Centre to Centre.

Sheesham 3½′ Centre to Centre.

Mango 3′ Centre to Centre.

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	2½	5¼	2¾	5¾	3	6	3	6¼	3¼	6½	3¼	6¾
7	3	6	3¼	6¼	3¼	6¼	3½	7	3½	7¼	3¾	7½
8	3¼	6½	3½	7	3½	7¼	3¾	7¾	4	8	4	8¼
9	3½	7¼	3¾	7¾	4	8	4¼	8½	4¼	8¾	4½	9
10	3¾	7¾	4¼	8¼	4¼	8¾	4½	9¼	4¾	9½	4¾	9¾
11	4¼	8½	4½	9	4¾	9¼	5	10	5	10	5¼	10½
12	4½	9	4¾	9½	5	10	5¼	10½	5¼	10¾	5½	11¼
13	4¾	9½	5	10	5¼	10½	5½	11¼	5½	11¼	6	12
14	5	10	5¼	10¾	5½	11¼	5¾	11¾	6	12	6¼	12¾
15	5¼	10¾	5½	11¼	5¾	11¾	6¼	12½	6¼	12¾	6½	13¼
16	5½	11¼	5¾	11¾	6	12½	6½	13	6½	13¼	7	14
17	5¾	11¾	6¼	12½	6½	13	6¾	13¾	7	14	7¼	14¾
18	6	12¼	6½	13	6¾	13½	7	14¼	7¼	14½	7¾	15½
19	6¼	12¾	6¾	13½	7	14	7½	15	7½	15¼	8	16
20	6½	13¼	7	14	7¼	14¾	7¾	15½	7¾	15¾	8¼	16¾

Deodar, Chir or Kail 2½′ Contre to Centre.
Teak, Sal or Keekar 5′ ,, ,, ,,
Sheesham 4⅗′ ,, ,, ,,
Mango 3¾′ ,, ,, ,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6.	2¾	5¾	3	6	3	6¼	3¼	6½	3¼	6¾	3½	7
	3¼	6¼	3¼	6¾	3½	7	3¾	7½	3¾	7½	4	8
	3½	7	3¾	7½	3¾	7¾	4	8¼	4	8¼	4¼	8¾
	3¾	7¾	4	8	4¼	8½	4½	9	4½	9	4¾	9¾
10	4¼	8¼	4¼	8¾	4½	9¼	4¾	9¾	4¾	9¾	5¼	10½
11	4½	9	4¾	9½	5	10	5¼	10½	5½	10½	5½	11¼
12	4¾	9½	5	10	5¼	10½	5½	11¼	5¼	11¼	6	12
13	5	10	5¼	10¾	5½	11¼	5¾	11¾	6	12	6¼	12¾

Table of Scantlings for BEAMS—continued.

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
14	5¼	10¾	5¼	11¼	5¾	11¾	6¼	12½	6¼	12¾	6¾	13½
15	5½	11¼	6	12	6¼	12½	6½	13¼	6½	13¼	7	14¼
16	5¾	11¾	6¼	12½	6½	13	6¾	13¾	7	14	7¼	14¾
17	6¼	12½	6½	13	6¾	13¾	7¼	14½	7¼	14¾	7¾	15½
18	6½	13	6¾	13¾	7	14¼	7½	15	7¾	15½	8	16¼
19	6¾	13½	7	14¼	7½	15	7¾	15¾	8	16	8½	17
20	7	14	7¼	14¾	7¾	15½	8	16¼	8¼	16¾	8¾	17¾

Deodar, Chir or Kail 3′ Centre to Centre.

Teak, Sal or Keekar 6′ „ „ „

Sheesham 5¼′

Mango 4½′

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3	6	3	6¼	3¼	6½	3½	7	3½	7	3¾	7½
7	3¼	6¾	3½	7	3½	7¼	3¾	7¾	4	8	4	8¼
8	3½	7¼	3¾	7¾	4	8	4¼	8½	4¼	8¾	4½	9¼
9	4	8	4¼	8½	4¼	8¾	4¾	9½	4¾	9½	5	10¼
10	4¼	8¾	4½	9¼	4¾	9½	5	10¼	5¼	10½	5½	11
11	4½	9¼	5	10	5	10¼	5½	11	5½	11¼	5¾	11¾
12	5	10	5¼	10½	5½	11	5¾	11¾	6	12	6¼	12½
13	5¼	10½	5½	11¼	5¾	11¾	6¼	12½	6¼	12½	6½	13¼
14	5½	11¼	5¾	11¾	6¼	12½	6½	13¼	6½	13¼	7	14
15	5¾	11¾	6¼	12½	6½	13	6¾	13¾	7	14	7½	15
16	6¼	12½	6½	13	6¾	13¾	7¼	14½	7½	14¾	7¾	15½
17	6½	13	6¾	13¾	7	14¼	7½	15¼	7¾	15½	8	16¼
18	6¾	13½	7	14¼	7½	15	8	16	8	16¼	8½	17
19	7	14	7½	15	7¾	15½	8¼	16½	8¼	16¾	8¾	17¾
20	7¼	14¾	7¾	15½	8	16¼	8½	17¼	8¾	17½	9¼	18½

Table of Scantlings for BEAMS—continued.

Deodar, Chir or Kail 3½′ Centre to Centre.
Teak, Sal or Keeker 7′ ,, ,, ,,
Sheesham 6⅛′ ,, ,, ,,
Mango 5¼′ ,, ,, ,,

Span.	Distributed load in lb., per square foot.											
	80 lb		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3	6¼	3¼	6½	3¼	6¾	3½	7¼	3½	7¼	3¾	7¾
7	3½	7	3½	7¼	3¾	7¾	4	8	4	8¼	4¼	8¾
8	3¾	7¾	4	8	4¼	8½	4½	9	4½	9	4¾	9½
9	4	8¼	4¼	8¾	4½	9¼	4¾	9¾	5	10	5¼	10½
10	4½	9	4¾	9½	5	10	5¼	10½	5¼	10¾	5½	11¼
11	4¾	9¾	5	10¼	5¼	10¾	5½	11¼	5¾	11¼	6	12¼
12	5	10¼	5½	11	5¾	11½	6	12	6	12¼	6½	13
13	5½	11	5¾	11½	6	12¼	6½	13	6½	13	7	14
14	5¾	11¾	6	12¼	6½	13	6¾	13¾	7	14	7¼	14¾
15	6	12¼	6½	13	6¾	13½	7¼	14½	7½	14½	7¾	15½
16	6½	13	6¾	13½	7	14¼	7½	15	7¾	15¼	8	16¼
17	6¾	13½	7	14¼	7½	15	7¾	15¾	8	16	8½	17
18	7	14	7½	15	7¾	15½	8¼	16½	8¼	16¾	8¾	17¾
19	7¼	14¾	7¾	15½	8	16¼	8½	17¼	8¾	17½	9¼	18½
20	7½	15¼	8	16	8¼	16¾	9	18	9	18¼	9¾	19¼

Deodar, Chir or Kail 4′ Centre to Centre.
Teak, Sal or Keeker 8′ ,, ,, ,,
Sheesham 7′ ,, ,, ,,
Mango 6′ ,, ,, ,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¼	6½	3¼	6¾	3½	7	3¾	7½	3¾	7½	4	8
7	3½	7¼	3¾	7½	4	8	4	8¼	4¼	8½	4½	9
8	4	8	4	8¼	4¼	8¾	4½	9¼	4¾	9½	5	10
9	4¼	8¾	4½	9	4¾	9½	5	10¼	5	10¼	5¼	10¾
10	4¾	9½	4¾	9¾	5¼	10¼	5½	11	5½	11¼	5¾	11¾
11	5	10	5¼	10½	5½	11¼	5¾	11¾	6	12	6¼	12¾
12	5¼	10¾	5½	11¼	6	12	6¼	12½	6¼	12¾	6¾	13½
13	5½	11¼	6	12	6¼	12½	6½	13¼	6¾	13½	7	14¼

Table of Scantlings for BEAMS—continued.

Span.	Distributed load in lb., per square foot.											
	80 lb		100 lb		120 lb		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins.	Ins.	Ins.	Ins.
14	6	12	6¼	12¼	6½	13¼	7	14	7	14¼	7½	15¼
15	6¼	12¼	6½	13¼	7	14	7½	15	7½	15	8	16
16	6½	13¼	7	14	7½	14¾	7¾	15½	7¾	15¾	8¼	16¾
17	7	14	7¼	14¾	7¾	15½	8	16¼	8¼	16½	8¾	17½
18	7¼	14½	7¾	15½	8	16¼	8½	17	8½	17¼	9	18¼
19	7½	15¼	8	16	8¼	16¾	8¾	17¾	9	18	9½	19
20	7¾	15¾	8¼	16¾	8¾	17½	9¼	18½	9¼	18¾	9¾	19¾

Deodar, Chir or Kail 4½′ Centre to Centre.

Teak, Sal or Keekar 9′ „ „ „

Sheesham 7⅞′ „ „ „

Mango 6¾′ „ „ „

Ft	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¼	6½	3½	7	3½	7	3¾	7¾	3¾	7¾	4	8¼
7	3½	7¼	3¾	7¾	4	8	4¼	8½	4¼	8¾	4½	9¼
8	4	8	4¼	8½	4½	9	4¾	9½	4¾	9¾	5	10¼
9	4¼	8¾	4¾	9½	4¾	9¾	5¼	10½	5¼	10½	5½	11¼
10	4¾	9½	5	10¼	5¼	10¾	5¼	11¼	5¾	11½	6	12¼
11	5	10¼	5½	11	5¾	11¼	6	12	6	12¼	6½	13
12	5½	11	5¾	11¾	6	12½	6½	13	6½	13¼	7	14
13	5¾	11¾	6¼	12½	6½	13	6¾	13¾	7	14	7¼	14¾
14	6¼	12½	6½	13¼	6¾	13¾	7¼	14½	7¼	14¾	7½	15½
15	6½	13	6¾	13¾	7½	14½	7½	15¼	7¾	15½	8¼	16½
16	6¾	13¾	7¼	14½	7¾	15¾	8	16	8	16¼	8½	17¼
17	7	14¼	7½	15¼	8	16	8¼	16¾	8½	17	9	18
18	7½	15	8	16	8¼	16½	8¾	17½	8¾	17¾	9¼	18¾
19	7¾	15½	8¼	16½	8½	17½	9	18¼	9¼	18½	9¾	19¾
20	8	16¼	8½	17¼	9	18	9½	19	9½	19¼	10½	20½

Table of Scantlings for BEAMS—continued.

Deodar, Chir or Kail 5′ Centre to Centre.
Teak, Sal or Keekar 10′ „ „ „
Sheesham 8¾′ „ „ „
Mango 7½′ „ „ „

Distributed load in lb., per square foot.

Span.	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¼	6¾	3½	7	3¾	7½	3¾	7¾	4	8	4¼	8½
7	3¾	7½	4	8	4	8¼	4¼	8¾	4½	9	4¾	9½
8	4	8¼	4¼	8¾	4½	9¼	4¾	9¾	5	10	5¼	10½
9	4½	9	4¾	9¾	5	10¼	5¼	10¾	5¼	10¼	5¾	11½
10	4¾	9¾	5¼	10½	5½	11	5¾	11½	5¾	11¾	6¼	12½
11	5¼	10½	5½	11¼	5¾	11¾	6¼	12½	6¼	12¾	6½	13½
12	5½	11¼	6	12	6¼	12½	6½	13¼	6¾	13½	7	14¼
13	6	12	6¼	12¾	6½	14¼	7	14	7	14¼	7½	15¼
14	6¼	12¾	6¾	13½	7	14	7½	15	7½	15¼	8	16
15	6½	13¼	7	14¼	7½	15	7¾	15¾	8	16	8½	17
16	7	14	7¼	14¾	7¾	15½	8¼	16½	8¼	16¾	8¾	17¾
17	7¼	14¾	7¾	15½	8	16¼	8½	17¼	8¾	17½	9¼	18½
18	7¾	15½	8	16¼	8½	17	9	18	9	18¼	9½	19¼
19	8	16	8½	17	8¾	17¾	9¼	18¾	9½	19	10	20
20	8¼	16¾	8¾	17¾	9¼	18½	9¾	19½	9¾	19¾	10½	21

Deodar, Chir or Kail 5½′ Centre to Centre
Teak, Sal or Keekar 11′ „ „
Sheesham 9⅝′ „ „
Mango 8¼′ „ „

Ft	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¼	6¾	3½	7¼	3¾	7½	4	8	4	8¼	4¼	8¾
7	3¾	7¾	4	8¼	4¼	8½	4½	9	4½	9¼	4¾	9¾
8	4¼	8½	4½	9	4¾	9½	5	10	5	10¼	5¼	10¾
9	4½	9¼	5	10	5	10¼	5½	11	5½	11	5¾	11¾
10	5	10	5¼	10¾	5¼	11¼	6	12	6	12	6¼	12¾
11	5¼	10¾	5¾	11½	6	12	6¼	12¾	6½	13	6¾	13¼
12	5¾	11½	6	12¼	6½	13	6¾	13½	6¾	13¼	7¼	14½
13	6	12¼	6½	13	6¾	13¾	7¼	14½	7¼	14¾	7¾	15½

Table of Scantlings for BEAMS—continued.

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
14	6½	13	6¾	13¾	7¼	14½	7¾	15½	7¾	15½	8¼	16½
15	6¾	13¾	7¼	14½	7½	15¼	8	16¼	8	16¼	8½	17¼
16	7¼	14½	7½	15¼	8	16	8½	17	8½	17	9	18¼
17	7½	15	8	16	8¼	16¾	8¼	17¾	9	18	9½	19
18	7¾	15¾	8¼	16¾	8¾	17½	9¼	18¼	9¼	18¾	9¾	19¾
19	8¼	16½	8¾	17¼	9	18¼	9½	19¼	9¾	19½	10¼	20½
20	8½	17	9	18	9½	19	10	20	10	20¼	10¾	21½

Deodar, Chir or Kail 6′ Centre to Centre.

Teak, Sal or Keekar 12′ ,, ,,

Shoosham 10½′ ,, ,,

Mango 9′ ,, ,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins,
6	3½	7	3¾	7½	3¾	7¾	4	8¼	4¼	8½	4¼	8¾
7	4	8	4	8¼	4¼	8¾	4½	9¼	4¾	9½	5	10
8	4¼	8¾	4½	9¼	4¾	9¾	5	10¼	5¼	10½	5½	11
9	4¾	9½	5	10¼	5¼	10½	5½	11¼	5¾	11½	6	12
10	5¼	10¼	5½	11	5¾	11½	6	12¼	6	12¼	6½	13
11	5½	11¼	5¾	11¾	6	12¼	6½	13	6½	13¼	7	14
12	6	12	6¼	12½	6½	13	7	14	7	14¼	7½	15
13	6¼	12½	6½	13¼	7	14	7¼	14¾	7½	15	8	16
14	6½	13¼	7	14	7¼	14¾	7½	15½	7¾	15¾	8¼	16¾
15	7	14	7½	15	7¾	15½	8¼	16½	8¼	16¾	8¾	17¾
16	7½	14¾	7¾	15½	8	16¼	8½	17¼	8¾	17½	9¼	18½
17	7¾	15½	8	16¼	8½	17	9	18	9	18¼	9¾	19½
18	8	16¼	8½	17	8¾	17¾	9¼	18¾	9½	19	10	20¼
19	8¼	16¾	8¾	17¾	9¼	18½	9¾	19¾	10	20	10½	21
20	8¾	17½	9½	18½	9½	19¼	10¼	20½	10¼	20¾	11	22

***Table of Scantlings for BEAMS*—continued.**

Deodar, Chir or Kail	6½′	Centre to	Centre.
Teak, Sal or Keekar	13′	,,	,,
Sheesham	11⅜′	,,	,,
Mango	9¾′	,,	,,

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins.	Ins.
6	3½	7¼	3¾	7½	4	8	4¼	8½	4¼	8½	4½	9
7	4	8	4¼	8½	4½	9	4¾	9½	4¾	9½	5	10¼
8	4½	9	4¾	9½	5	10	5¼	10½	5¼	10½	5½	11¼
9	4¾	9¾	5	10¼	5¼	10¾	5¾	11½	5¾	11½	6	12¼
10	5¼	10½	5½	11¼	5¾	11¾	6	12¼	6¼	12½	6½	13¼
11	5½	11¼	6	12	6½	12½	6½	13¼	6¾	13½	7	14¼
12	6	12	6¼	12¾	6¾	13½	7	14¼	7¼	14½	7½	15¼
13	6¼	12¾	6¾	13½	7	14¼	7½	15	7½	15¼	8	16¼
14	6¾	13½	7¼	14½	7½	15	8	16	8	16¼	8½	17
15	7	14¼	7½	15¼	7¾	15¾	8¼	16¾	8½	17	9	18
16	7½	15	8	16	8¼	16¾	8¾	17½	9	18	9½	19
17	7¾	15¾	8¼	16½	8¾	17½	9¼	18½	9¼	18¾	9¾	19¾
18	8¼	16½	8¾	17½	9	18¼	9½	19¼	9¾	19½	10¼	20½
19	8½	17	9	18	9½	19	10	20	10¼	20½	10¾	21½
20	8¾	17¾	9¼	18¾	9¾	19¾	10¼	20¾	10½	21¼	11	22¼

Deodar, Chir or Kail	7′	Centre to	Centre.
Teak, Sal or Keekar	14′	,,	,,
Sheesham	12¼′	,,	,,
Mango	10½′	,,	,,

Span.	80 lb. *b*	80 lb. *d*	100 lb. *b*	100 lb. *d*	120 lb. *b*	120 lb. *d*	150 lb. *b*	150 lb. *d*	160 lb. *b*	160 lb. *d*	200 lb. *b*	200 lb. *d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3½	7¼	3¾	7¾	4	8	4¼	8½	4¼	8¾	4½	9
7	4	8¼	4¼	8¾	4½	9	4¾	9½	4¾	9¾	5¼	10
8	4½	9	4¾	9½	5	10	5¼	10½	5¼	10¼	5¾	11½
9	5	10	5¼	10½	5½	11	5¾	11½	5¾	11¾	6¾	12½
10	5¼	10¾	5½	11¼	6	12	6¼	12½	6¼	12¾	[illegible]	13½
11	5¾	11½	6	12¼	6¼	12¾	6¾	13½	6¾	13¾	7¼	14½
12	6	12¼	6½	13	6¾	13	7¼	14½	7¼	14¾	7¾	15½
13	6½	13	7	14	7¼	14½	7½	15¼	7¾	15½	8¼	16½

Table of Scantlings for BEAMS—continued.

Span.	Distributed load in lbs., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
14	7	14	7¼	14¾	7½	15¼	8	16¼	8¼	16½	8¾	17½
15	7½	14½	7¾	15½	8	16	8½	17	8½	17¼	9¼	18½
16	7¾	15¼	8	16¼	8½	17	9	18	9	18¼	9½	19¼
17	8	16	8½	17	8¾	17¾	9¼	18¾	9½	19	10	20¼
18	8¼	16¾	8¾	17¾	9¼	18½	9¾	19½	10	20	10½	21
19	8¾	17½	9¼	18½	9¾	19¼	10¼	20½	10¼	20¾	11	22
20	9	18¼	9¾	19½	10	20	10½	21¼	10¾	21½	11¼	22¾

Doodar, Chir or Kail 7½′ Centre to Centre.

Teak, Sal or Keokar 15′ ,, ,, ,,

Sheesham 13⅛′ ,,

Mango 11¼′ ,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¾	7½	3¾	7¾	4	8¼	4¼	8¾	4¼	8¾	4½	9¼
7	4	8¼	4¼	8¾	4½	9¼	4¾	9¾	5	10	5¼	10½
8	4½	9¼	4¾	9¾	5	10¼	5¼	10¾	5½	11	5¾	11½
9	5	10¼	5¼	10¾	5½	11¼	5¾	11¾	6	12	6¼	12¾
10	5½	11	5¾	11½	6	12¼	6¼	12¾	6½	13	6¾	13¾
11	5¾	11¾	6¼	12½	6½	13	6¾	13¾	7	14	7¼	14¾
12	6¼	12½	6½	13¼	7	14	7¼	14½	7½	15	7¾	15¾
13	6½	13¼	7	14	7¼	14¾	7¾	15½	8	16	8¼	16¾
14	7	14	7½	15	7½	15½	8¼	16½	8¼	16¾	8¾	17¾
15	7½	15	7¾	15¾	8¼	16½	8½	17¼	8¾	17¾	9¼	18¾
16	7¾	15½	8¼	16½	8½	17¼	9	18¼	9¼	18½	9¾	19½
17	8	16¼	8½	17¾	9	18	9½	19	9¾	19½	10¼	20½
18	8½	17	9	18	9¼	18¾	9¾	19¾	10	20¼	10¾	21½
19	8¾	17¾	9¼	18¾	9¾	19¾	10¼	20¾	10½	21	11	22¼
20	9¼	18½	9¾	19½	10¼	20½	10¾	21½	11	22	11½	23¼

Table of Scantlings for BEAMS—continued.

Deodar, Chir or Kail	8′	Centre to Centre.	
Teak, Sal or Keekar	16′	,,	,,
Sheesham	14′	,,	,,
Mango	12′	,,	,,

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Feet.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¾	7½	4	8	4¼	8½	4¼	8¾	4½	9	4¾	9½
7	4¼	8½	4½	9	4¾	9½	5	10	5	10	5½	10¾
8	4¾	9½	5	10	5¼	10½	5½	11	5½	11¼	6	11¾
9	5	10¼	5¼	10¾	5¾	11½	6	12	6	12¼	6½	13
10	5½	11¼	5¾	11¾	6	12¼	6½	13	6½	13¼	7	14
11	6	12	6¼	12¾	6½	13¼	7	14	7	14¼	7½	15
12	6¼	12¾	6¾	13½	7	14¼	7½	15	7½	15¼	8	16
13	6¾	13½	7	14¼	7½	15	8	16	8	16¼	8½	17
14	7	14¼	7½	15¼	7¾	15¾	8¼	16¾	8½	17¼	9	18
15	7½	15	8	16	8¼	16¾	8¾	17¾	9	18	9½	19
16	7¾	15¾	8¼	16¾	8¼	17½	9¼	18½	9¼	18¾	10	20
17	8¼	16½	8¾	17½	9	18¼	9¾	19½	9¾	19¾	10½	21
18	8½	17¼	9	18¼	9½	19	10	20¼	10	20½	11	21¾
19	9	18	9½	19	10	20	10½	21	10¾	21½	11¼	22¾
20	9¼	18¾	9¾	19¾	10¼	20¾	11	22	11	22¼	11¾	23½

Deodar, Chir or Kail	8½′	Centre to Centre.	
Teak, Sal or Keekar	17′	,,	,,
Sheesham	14⅞′	,,	,,
Mango	12¾′	,,	,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¾	7¾	4	8	4¼	8½	4½	9	4½	9	4¾	9¾
7	4¼	8½	4½	9	4¾	9½	5	10	5	10¼	5½	10¾
8	4¾	9½	5	10	5¼	10½	5½	11	5½	11¼	6	12
9	5¼	10½	5½	11	5¾	11½	6	12¼	6¼	12¼	6½	13
10	5½	11¼	6	12	6¼	12½	6½	13¼	6¾	13½	7	14¼
11	6	12	6¼	12¾	6¾	13½	7	14¼	7¼	14½	7½	15¼
12	6½	12	6¾	13¾	7	14½	7½	15	7¾	15½	8	16¼
13	6¾	13¾	7¼	14½	7½	15¼	8	16	8	16¼	8½	17¼

Table of Scantlings for BEAMS—concluded.

Span.	Distributed load in lb., per square foot.											
	80 lb.		100 lb.		120 lb.		150 lb.		160 lb.		200 lb.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
14	7¼	14½	7¾	15½	8	16	8½	17	8½	17¼	9	18¼
15	7½	15¼	8	16¼	8½	17	9	18	•9	18¼	9½	19¼
16	8	16	8½	17	8¾	17¾	9¼	18¾	9½	19	10	20¼
17	8¼	16¾	8¾	17¾	9¼	18½	9¾	19¾	10	20	10½	21¼
18	8¾	17½	9¼	18½	9¾	19½	10¼	20½	10½	21	11	22
19	9	18¼	9¾	19¼	10	20¼	10¾	21½	10¾	21¾	11½	23
20	9½	19	10	20	10½	21	11	22¼	11¼	22½	12	24

Deodar, Chir or Kail 9′ Centre to Centre.

Teak, Sal or Keekar 18′ ,, ,,

Sheesham 15¾′ ,, ,,

Mango 13½′ ,,

Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
6	3¾	7¾	4	8¼	4¼	8½	4½	9¼	4½	9¼	4¾	9¾
7	4¼	8¾	4½	9¼	4¾	9¾	5	10¼	5¼	10½	5½	11
8	4¾	9¾	5	10¼	5¼	10¾	5½	11¼	5¾	11½	6	12¼
9	5¼	10½	5½	11¼	5¾	11¾	6	12¼	6¼	12½	6½	13¼
10	5¾	11½	6	12	6¼	12¾	6½	13¼	6¾	13½	7¼	14½
11	6	12¼	6½	13	6¾	13½	7	14¼	7¼	14½	7¾	15½
12	6½	13	7	14	7¼	14½	7½	15¼	7¾	15½	8¼	16½
13	7	14	7¼	14¾	7¾	15½	8	16¼	8¼	16½	8¾	17½
14	7¼	14¾	7¾	15½	8	16¼	8½	17¼	8¾	17½	9¼	18½
15	7¾	15½	8¼	16½	8½	17¼	9	18¼	9¼	18½	9¾	19½
16	8	16¼	8½	17¼	9	18	9½	19	9¾	19½	10¼	20½
17	8½	17	9	18	9½	19	10	20	10	20¼	10¾	21½
18	8¾	17¾	9½	19	9¾	19¾	10¼	20¾	10½	21¼	11¼	22½
19	9¼	18½	9¾	19¾	10¼	20½	10¾	21¾	11	22	11½	23¼
20	9½	19¼	10¼	20½	10½	21¼	11¼	22½	11½	23	12	24¼

ROLLED STEEL BEAMS.

Rolled Iron Beams are now things of the past, and hence tables are given for *Rolled Steel Beams* only, from which the size of beams can be determined at a glance, given the *clear span* and *spacings*, or the spacing can be determined, given the size of beam and *clear span*.

Explanation of Tables.

1. *Clear span* means clear width of the room or culvert from wall to wall.
2. *Safe load* per running foot=load per S. ft. spacing in feet Centre to Centre
3. There are five columns given for spacing, one for

For Single storied buildings {
80 lb—this is for very light roof ;
100 lb—this is for ordinary flat roof consisting of *beams*, *kurrees*, *bricks* and *tiles*, *terrace* or *mud* ;
125 lb—this is for *jack arching* ;
}

150 lb—this is for double storied buildings ;
200 lb—this is for bridges.

Note.—If a problem does not come within the meaning above given, for instance if the girder is used as a bressummer, or in pent roof or in any other place where less than 80 lb per S. foot, is required or more than 200, divide the *weight per running foot*, by the *weight per S. foot* and you will get the *spacing*.

General Directions.

For light loads, *i.e.*, up to 100 lb., the depth of beam should be ½ inch per foot of the width of the room. For instance, for 16 feet minimum depth of 8″ is required.

For loads over 100 lb. and up to 150 lb. add one inch to the size above given, that is to say, for 16 ft. make the beam 9″ deep.

For loads over 150 lb., add 2 inches, *i. e.*, for 16 feet span make depth 10″.

Having thus determined the depth, the necessary spacing should be seen from the Tables, which is to be taken as the *maximum spacing*.

Bearing.

No beams should bear on the walls less than one foot, in rare cases it might be 9″ but *never less*, give 15″ bearing or even 18″ if possible.

TABLE OF ROLLED STEEL BEAMS.

Table of spacings for distributed loads.

Sec. in inches	Clear span.	Safe load per sq. ft.	Spacings (in feet) for Weight of roof (in lbs). 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
3×1¾ @ 4 lbs.	4	627	..	6·25	5·00	4·00	3·25
	5	379	4·75	3·75	3·00	2·50	2·00
	6	268	3·25	2·75	2·00	1·75	1·25
	7	201	2·50	2·00	1·50	1·25	1·00
	8	169	2·00	1·75	1·25	1·00	..
	9	120	1·50	1·25	1·00	..	..
	10	98	1·25	1·00	..	..	..
3×3 @ 8·5 lbs.	5	896	..	..	7·00	6·00	4·50
	6	627	..	6·25	5·00	4·00	3·00
	7	470	5·75	4·75	3·75	3·00	3·25
	8	336	4·25	3·25	2·50	2·25	1·50
	9	268	3·25	2·50	2·00	1·75	1·25
	10	224	2·75	2·25	1·75	1·50	1·00
	12	156	2·00	1·50	1·25	1·00	..
	14	132	1·50	1·25	1·00	..	..
4×1¾ @ 5 lbs.	5	672	..	6·75	5·25	4·50	3·25
	6	448	5·50	4·50	3·50	3·00	2·25
	7	336	4·25	3·25	2·50	2·25	1·50
	8	246	3·00	2·50	2·00	1·50	1·25
	9	201	2·50	2·00	1·50	1·25	1·00
	10	156	2·00	1·50	1·25	1·00	..
	12	112	1·25	1·00	..	..	..
	14	82	1·00	..	..	..	..
4×3 @ 9·5 lbs.	7	680	..	6·75	5·25	4·50	3·25
	8	516	6·25	5·00	4·00	3·25	2·50
	9	403	5·00	4·00	3·25	2·50	2·00
	10	336	4·25	3·25	2·50	2·25	1·50
	11	270	3·25	2·75	2·25	1·75	1·25
	12	224	2·75	2·25	1·75	1·50	1·00
	14	156	2·00	1·50	1·25	1·00	..

Sec. in inches	Clear span.	Safe load per sq. ft.	Spacings (in feet) for Weight of roof (in lbs). 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
4¾×1¾ @ 6·5 lbs.	6	672	..	6·75	5·25	4·50	3·25
	7	515	..	5·00	4·00	3·25	2·50
	8	380	4·75	3·75	3·00	2·50	1·75
	9	313	3·75	3·00	2·50	2·00	1·50
	10	246	3·00	2·50	2·00	1·50	1·25
	11	201	2·50	2·00	1·50	1·25	1·00
	12	170	2·00	1·75	1·25	1·00	..
5×3 @ 11 lbs.	7	985	..	..	..	6·50	4·75
	8	761	..	7·50	6·00	5·00	3·75
	9	582	7·25	5·75	4·50	3·75	2·75
	10	448	5·50	4·50	3·50	3·00	2·25
	11	403	5·00	4·00	3·25	2·50	2·00
	12	336	4·25	3·25	2·50	2·25	1·50
	13	290	3·50	2·75	2·25	1·75	1·50
	14	246	3·00	2·50	2·00	1·50	1·25
5×4½ @ 18 lbs.	8	1254	..	..	..	..	6·25
	9	1008	..	..	..	6·75	5·00
	10	807	..	..	6·25	5·25	4·00
	11	672	..	6·75	5·25	4·50	3·25
	12	559	7·00	5·50	4·25	3·75	2·75
	13	448	5·50	4·50	3·50	3·00	2·25
	14	403	5·00	4·00	3·25	2·50	2·00
	15	358	4·25	3·50	2·75	2·25	1·75
	16	313	3·75	3·00	2·50	2·00	1·50
6×3 @ 12 lbs.	8	940	..	..	7·50	6·25	4·75
	9	739	..	7·25	5·75	4·75	3·50
	10	604	7·50	6·00	4·75	4·00	3·00
	11	492	6·00	4·75	3·75	3·25	2·50
	12	403	5·00	4·00	3·25	2·50	2·00
	13	358	4·25	3·50	2·75	2·25	1·75
	14	313	3·75	3·00	2·50	2·00	1·50
	15	268	3·25	2·50	2·00	1·75	1·25
	16	224	2·75	2·25	1·75	1·50	1·00
	18	179	2·25	1·75	1·50	1·25	..

Table of spacings for distributed loads.—contd.

Section in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.). 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
6×4½ @ 20 lbs.	9	1276	..	..	..	8·50	6·25
	10	1030	..	..	8·25	6·75	5·00
	11	851	..	8·50	6·75	5·50	4·25
	12	716	9·00	7·00	5·75	4·75	3·50
	13	604	7·50	6·00	4·75	4·00	3·00
	14	515	6·25	5·00	4·00	3·25	2·50
	15	448	5·50	4·50	3·50	3·00	2·25
	16	403	5·00	4·00	3·25	2·50	2·00
	17	358	4·25	3·50	2·75	2·25	1·75
	18	313	3·75	3·00	2·50	2·00	1·50
6×5 @ 25 lbs.	10	1299	..	..	..	8·50	6·50
	11	1075	..	..	8·50	7·00	5·00
	12	896	..	9·00	7·00	6·00	4·50
	13	761	..	7·50	6·00	5·00	3·75
	14	672	8·25	6·75	5·25	4·50	3·25
	15	582	7·25	5·75	4·50	3·75	2·75
	16	492	6·00	4·75	3·75	3·25	2·50
	17	448	5·50	4·50	3·50	3·00	2·25
	18	403	5·00	4·00	3·25	2·50	2·00
7×4 @ 16 lbs.	10	985	..	9·75	7·75	6·50	4·75
	11	828	..	8·25	6·50	5·50	4·00
	12	694	8·50	7·00	5·50	4·50	3·50
	13	582	7·25	5·75	4·50	3·75	2·75
	14	492	6·00	4·75	3·75	3·25	2·50
	15	448	5·50	4·50	3·50	3·00	2·25
	16	380	4·75	3·75	3·00	2·50	1·75
	17	336	4·25	3·25	2·50	2·25	1·50
	18	291	3·50	2·75	2·25	1·75	1·50
	20	246	3·00	2·50	2·00	1·50	1·25
	22	201	2·50	2·00	1·50	1·25	1·00

Section in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.). 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
8×4 @ 18 lbs.	10	1232	..	..	9·75	8·25	6·00
	12	851	..	8·50	6·75	5·50	4·25
	13	716	9·00	7·00	5·75	4·75	3·50
	14	649	8·00	6·50	5·00	4·25	3·25
	15	560	7·00	5·50	4·50	3·75	2·75
	16	470	5·75	4·75	3·75	3·00	2·25
	17	425	5·25	4·25	3·25	2·75	2·00
	18	380	4·75	3·75	3·00	2·50	1·75
	19	306	3·75	3·00	2·50	2·00	1·50
	20	281	3·50	2·75	2·25	1·75	1·25
	22	246	3·00	2·50	2·00	1·50	1·25
8×5 @ 28 lbs.	10	1881	..	..	..	..	9·25
	11	1635	..	..	..	10·75	8·00
	12	1388	..	..	11·00	9·25	6·75
	13	1164	..	11·50	9·25	7·75	5·75
	14	1008	..	10·00	8·00	6·75	5·00
	15	873	10·75	8·75	7·00	5·75	4·25
	16	784	9·75	7·75	6·25	5·25	3·75
	18	604	7·50	6·00	4·75	4·00	3·00
	20	495	6·00	5·00	4·00	3·25	2·50
	22	425	5·25	4·25	3·25	2·75	2·00
	24	336	4·25	3·25	2·50	2·25	1·50
8×6 @ 35 lbs.	12	1702	..	..	..	11·25	8·50
	13	1478	..	..	11·75	9·75	7·25
	14	1321	..	..	10·50	8·75	6·50
	15	1120	..	11·00	9·00	7·50	5·50
	16	963	12·00	9·50	7·75	6·25	4·75
	18	761	9·50	7·50	6·00	5·00	3·75
	19	672	8·25	6·75	5·25	4·50	3·25
	20	600	7·50	6·00	4·75	4·00	3·00
	21	560	7·00	5·50	4·25	3·75	2·75
	22	492	6·00	4·75	3·75	3·25	2·50

Table of spacings for distributed loads.—contd.

Sec. in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.) 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft
9″×4″ @ 21 lbs.	12	1120	..	11·00	9·00	7·50	5·50
	13	963	12·00	9·50	7·75	6·25	4·75
	14	800	10·00	8·00	6·25	5·25	4·00
	15	716	9·00	7·00	5·75	4·75	3·50
	16	677	8·50	6·75	5·25	4·50	3·25
	17	537	6·75	5·25	4·25	3·50	2·50
	18	492	6·00	4·75	3·75	3·25	2·50
	19	448	5·50	4·50	3·50	3·00	2·25
	20	403	5·00	4·00	3·25	2·50	2·00
	21	358	4·25	3·50	2·75	2·25	1·75
	22	313	3·75	3·00	2·50	2·00	1·50
	24	268	3·25	2·75	2·00	1·75	1·25
9¼×3¾ @ 21 5 lbs.	12	1125	..	11·25	9·00	7·50	5·50
	13	964	12·00	9·50	7·75	6·25	4·75
	14	801	10·00	8·00	6·25	5·25	4·00
	15	720	9·00	7·00	5·75	4·75	3·50
	16	680	8·50	6·75	5·25	4·50	3·25
	17	540	6·75	5·25	4·25	3·50	2 75
	18	495	6·00	5·00	4·00	3·25	2·50
	19	448	5·50	4·50	3·50	3·00	2·25
	20	404	5·00	4·00	3·25	2·50	2·00
	21	360	4·50	3·50	2·75	2·25	1·75
	22	314	3·75	3·00	2·50	2·00	1·50
	24	270	3·25	2·75	2·25	1·75	1·25
9×7 @ 58 lbs.	16	1779	..	..	..	11·75	8·75
	17	1568	..	..	12·25	10·25	7·75
	18	1411	..	..	11·25	9·25	7·00
	19	1254	..	12·50	10·00	8·25	6·25
	20	1144	..	11·25	9·00	7·50	5·75
	21	1030	12·75	10·25	8·25	6·75	5·00
	22	940	11·75	9·25	7·50	6·25	4·75
	23	851	10·50	8·50	6·75	5·50	4·25
	25	716	9·00	7·00	5·75	4·75	3·50
	26	672	8·25	6·75	5·25	4·50	3·25
10×4·66 @ 25 lbs.	14	1120	..	11·00	9·00	7·50	5·50
	15	963	12·00	9·50	7·75	6·25	4·75
	16	851	10·50	8·50	6·75	5·50	4·25
	17	761	9·50	7·50	6·00	5·00	3·75
	18	672	8·25	6·75	5·25	4·50	3·25
	19	604	7·50	6·00	4·75	4·00	3·00
	20	537	6·75	5·25	4·25	3·50	2·50
	22	448	5·50	4·50	3·50	3·00	2·25
	24	380	4·75	3·75	3·00	2·50	1·75
	26	313	3·75	3·00	2·50	2·00	1·50
	28	268	3·25	2·75	2·00	1·75	1·25
	30	224	2·75	2·25	1·75	1·50	1·00
10×5 @ 30 lbs.	14	1347	..	..	10·75	9·00	6·75
	15	1187	..	11·75	9·50	7·75	5·75
	16	1008	12·50	10·00	8·00	6·75	5·00
	17	896	11·00	9·00	7·00	6·00	4·50
	18	784	9·75	7·75	6·25	5·25	3·75
	19	716	9·00	7·00	5·75	4·75	3·50
	20	649	8·00	6·50	5·00	4·25	3·25
	22	537	6·75	5·25	4 25	3·50	2·50
	24	448	5·50	4·50	3·50	3·00	2·25
	26	380	4·75	3·75	3·00	2·50	1·75
10×5 @ 35 lbs.	14	1523	..	..	12·00	10·00	7·50
	15	1300	..	..	10·25	8·50	6·50
	16	1164	..	11·50	9·25	7·75	5·75
	17	1030	12·75	10·25	9·25	6·75	5·00
	18	918	11·25	9·00	7·25	6·00	4·50
	19	806	10 00	8·00	6·25	5·25	4·00
	20	739	9·25	7·25	5·75	4·75	3·50
	22	604	7·50	6·00	4·75	4·00	3·00
	24	515	6·25	5·00	4·00	3·25	2·50
	26	448	5·50	4·50	3·50	3·00	2·25

Table of Spacings for distributed loads—contd.

Sec. in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.) 80	100	125	150	200
	Ft	lbs	Ft.	Ft.	Ft.	Ft.	Ft.
10×6 @ 42 lbs.	15	168	..	..	..	11·00	8·25
	16	1478	.	..	11·75	9·75	7·25
	17	1299	..	..	10·25	8·50	6·50
	18	1164	..	11·50	9 25	7·75	5·75
	19	1030	12·75	10·25	8·25	6·75	5·00
	20	940	11·75	9·25	7 50	6·25	4 75
	22	784	9 75	7·75	6 25	5·25	3·75
	24	672	8 25	6 75	5·25	4·50	3·25
	26	560	7 00	5·50	4 25	3·75	2·75
12×5 @ 70 lbs.	18	1904	..	..	..	12·75	9 50
	19	1635	..	..	..	10·75	8·00
	20	1523	..	.	12·00	10·00	7·50
	22	1254	..	12 50	10·00	8·25	6·25
	24	1052	..	10·50	8·25	7·00	5·25
	26	896	11·00	9·00	7·00	6·00	4·50
	28	784	9·75	7 75	6·25	5·25	3·75
	30	672	8·25	6·75	5·25	4·50	3·25
	32	582	7·25	5·75	4·50	3·75	2·75
	34	515	6 25	5·00	4·00	3·25	2·50
12×5 @ 32 lbs.	15	1456	..	..	11·75	9·75	7·25
	16	1276	..	12·75	10·00	8·50	6·25
	17	1120	..	11·00	9·00	7·50	5·50
	18	1008	12·50	10·00	8·00	6·75	5·00
	19	896	11·00	9·00	7·00	6·00	4·50
	20	806	10·00	8·00	6·25	5·25	4·00
	22	672	8·25	6·75	5·25	4·50	3·25
	24	560	7·00	5·50	4·25	3·75	2·75
	26	470	5·75	4·75	3·75	3·00	2·25
	28	403	5·00	4·00	3·25	2·50	2·00
	30	358	4·25	3·50	2·75	2·25	1·75
	32	313	3·75	3·00	2·50	2·00	1·50
12×5 @ 39 lbs.	15	1724	..	..	..	11·50	8·50
	16	1545	..	..	12·25	10·25	7·75
	17	1344	..	.	10·75	9·00	6·75
	18	1187	..	11·75	9·50	7·75	5·75
	19	1052	..	10·50	8·25	7·00	5·25
	20	953	12·00	9·50	7·50	6·25	4·75
	22	806	10 00	8·00	6 25	5·25	4·00
	24	672	8·25	6·75	5·25	4·50	3·25
	26	56	7·00	5·50	4·25	3·75	2·75
	28	472	5·75	4·75	3·75	3·00	2·25
	30	418	5·50	4·50	3·50	3·00	2·25
12×6 @ 44 lbs.	16	1836	..	..	..	12 25	9·00
	17	1613	..	..	.	10 75	8·00
	18	1434	..	..	11·50	9·50	7·00
	19	1299	..	..	10·25	8·50	6·50
	20	1165	..	11·50	9 25	7·75	5·75
	22	953	12·00	9·50	7·50	6·25	4·75
	24	806	10·00	8·00	6·25	5·25	4·00
	26	672	8·25	6·75	5·25	4·50	3·25
	28	582	7·25	5·75	4·50	3·75	2·75
	30	515	6·25	5·00	4·00	3·25	2·50
	32	448	5 50	4·50	3·50	3·00	2·25
	34	403	5 00	4·00	3·25	2·50	2·00
12×6 @ 54 lbs.	16	2172	..	..	..	..	10·75
	17	1926	..	..	..	..	9·50
	18	1724	..	..	..	11·50	8·50
	19	1545	..	..	12·25	10·25	7·75
	20	1388	..	..	11 00	9·25	6·75
	22	1142	..	11·25	9·00	7·50	5·75
	24	953	12·00	9·50	7·50	6·25	4·75
	26	828	10·25	8·25	6·50	5·50	4·00
	28	694	8·50	7·00	5·50	4·50	3·50
	30	607	7·50	6·00	4·75	4·00	3·00
	32	537	6·75	5·25	4·25	3·50	2·50
	34	473	5·75	4·75	3·75	3·00	2·25

Table of spacings for distributed loads.—contd.

Sec. in inches.	Clear span.	Safe load per sq. ft.	SPACINGS (IN FEET) FOR *Weight of roof (in lbs.)* 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
14 × 6 @ 46 lbs.	18	1730	..	..	..	11·50	8·50
	19	1551	..	..	12·25	10·25	7·75
	20	1392	..	..	11·00	9·25	7·00
	22	1151	..	11·50	9·00	7·50	5·75
	24	962	12·00	9·50	7·75	6·25	4·75
	26	832	10·25	8·25	6·75	5·50	4·00
	28	704	8·75	7·00	5·50	4·75	3·50
	30	611	7·50	6·00	5·00	4·00	3·00
	32	541	6·75	5·25	4·25	3·50	2·75
	34	481	6·00	4·75	3·75	3·00	2·25
	36	403	5·00	4·00	3·25	2·50	2·00
14×6 @ 57 lbs.	18	2105	..	..	..	..	10·50
	19	1881	..	..	..	12·50	9·50
	20	1702	..	..	..	11·25	8·50
	22	1411	..	..	11·25	9·25	7·00
	24	1164	..	11·50	9·25	7·75	5·75
	26	1008	12·50	10·00	8·00	6·75	5·00
	28	851	10·50	8·50	6·75	5·50	4·25
	30	739	9·25	7·25	5·75	4·75	3·50
	32	627	7·75	6·25	5·00	4·00	3·00
	34	582	7·25	5·75	4·50	3·75	2·75
	36	492	6·00	4·75	3·75	3·25	2·50
15×5 @ 42 lbs.	18	1568	..	..	12·50	10·25	7·75
	19	1411	..	..	11·25	9·25	7·00
	20	1276	..	12·75	10·00	8·50	6·25
	21	1122	..	11·25	9·00	7·50	5·50
	22	1052	..	10·50	8·25	7·00	5·25
	24	873	10·75	8·75	7·00	5·75	4·25
	26	739	9·25	7·25	5·75	4·75	3·50
	28	649	8·00	6·50	5·00	4·25	3·25
	30	560	7·00	5·50	4·25	3·75	2·75
	32	492	6·00	4·75	3·75	3·25	2·50
	34	425	5·25	4·25	3·25	2·75	2·00
	36	380	4·75	3·75	3·00	2·50	1·75

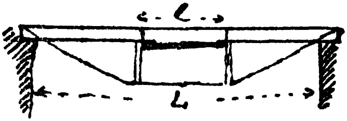
Sec. in inches.	Clear span.	Safe load per sq. ft.	SPACINGS (IN FEET) FOR *Weight of roof (in lbs.)* 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
15×6 @ 59 lbs.	20	1859	..	..	..	12·25	9·25
	21	1702	..	..	..	11·25	8·50
	22	1545	..	..	12·25	10·25	7·75
	23	1411	..	..	11·25	9·25	7·00
	24	1299	..	..	10·25	8·50	6·50
	25	1187	..	11·75	9·50	7·75	5·75
	26	1097	..	11·00	8·75	7·25	5·50
	28	940	11·75	9·25	7·50	6·25	4·75
	30	828	10·25	8·25	6·50	5·50	4·00
	32	716	9·00	7·00	5·75	4·75	3·50
	34	649	8·00	6·50	5·00	4·25	3·25
	36	560	7·00	5·50	4·25	3·75	2·75
16×6 @ 62 lbs.	21	1836	..	..	..	12·25	9·00
	22	1680	..	..	..	11·00	8·25
	23	1523	..	..	12·00	10·00	7·50
	24	1411	..	..	11·25	9·25	7·00
	26	1187	..	11·75	9·50	7·75	5·75
	28	1030	12·75	10·25	8·25	6·75	5·00
	30	896	11·00	9·00	7·00	6·00	4·50
	32	784	9·75	7·75	6·25	5·25	3·75
	34	694	8·50	7·00	5·50	4·50	3·50
	36	627	6·75	6·25	5·00	4·00	3·00
18×6 @ 55 lbs.	22	1658	..	..	..	11·00	8·25
	23	1500	..	..	12·00	10·00	7·50
	24	1398	..	..	11·00	9·25	7·00
	25	1276	..	12·75	10·00	8·50	6·25
	26	1187	..	11·75	9·50	7·75	5·75
	28	1025	12·75	10·25	8·25	6·75	5·00
	30	890	11·00	8·75	7·00	6·00	4·25
	32	764	9·50	7·50	6·00	5·00	3·75
	34	680	8·50	6·75	5·25	4·50	3·25
	36	625	7·75	6·25	5·00	4·00	3·00
	38	537	6·75	5·25	4·25	3·50	2·50
	40	472	5·75	4·75	3·75	3·00	2·25

Table of spacings for distributed loads.—contd.

Sec. in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.) 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
18 × 7 @ 75 lbs.							
	24	1993	..	..	..	..	10·00
	25	1814	..	..	..	12·00	9·00
	26	1680	..	..	..	11·00	8·25
	28	1496	..	..	12·50	10·00	7·50
	30	1254	..	12·00	10·00	8·25	6·25
	32	1120	..	11·00	9·00	7·50	5·50
	34	985	12·25	9·75	7·75	6·50	4·75
	36	873	11·00	8·75	7·00	5·75	4·25
	38	784	9·75	7·75	6·25	5·25	3·75
	40	716	9·00	7·00	5·75	4·75	3·50
	42	649	8·00	6·50	5·00	4·25	3·25
20 × 6¼ @ 65 lbs.							
	25	1680	..	..	..	11·00	8·25
	26	1568	..	..	12·50	10·25	7·75
	28	1344	..	..	10·75	9·00	6·75
	30	1164	..	11·50	9·25	7·75	5·75
	32	1030	12·75	10·25	8·25	6·75	5·00
	34	896	11·00	9·00	7·00	6·00	4·50
	36	806	10·00	8·00	6·25	5·25	4·00
	38	716	9·00	7·00	5·75	4·75	3·50
	40	649	8·00	6·50	5·00	4·25	3·25
	42	604	7·50	6·00	4·75	4·00	3·00
	44	537	6·75	5·25	4·25	3·50	2·50

Sec. in inches.	Clear span.	Safe load per rg. ft.	Spacings (in feet) for Weight of roof (in lbs.) 80	100	125	150	200
	Ft	lbs.	Ft.	Ft.	Ft.	Ft.	Ft.
20 × 7½ @ 89 lbs.							
	28	1904	..	..	..	12·75	9·50
	30	1657	..	..	..	11·00	8·25
	32	1456	..	..	11·50	9·75	7·25
	35	1209	..	12·00	9·75	8·00	6·00
	38	1030	12·75	10·25	8·25	6·75	5·00
	40	918	11·25	9·00	7·25	6·00	4·50
	42	851	10·50	8·50	6·75	5·50	4·25
	45	739	9·25	7·25	5·75	4·75	3·50
	48	649	8·00	6·50	5·00	4·25	3·25
	50	582	7·25	5·75	4·50	3·75	2·75
	52	537	6·75	5·25	4·25	3·50	2·50
24 × 7½ @ [illegible].00 lbs.							
	35	1612	..	..	..	10·75	8·00
	40	1232	..	..	9·75	8·25	6·00
	42	1050	..	11·00	9·00	7·50	5·50
	44	1008	12·50	10·00	8·00	6·75	5·00
	46	918	11·25	9·00	7·25	6·00	4·50
	48	851	11·00	8·50	6·75	5·50	4·25
	50	806	10·00	8·00	6·25	5·25	4·00
	52	716	9·00	7·00	5·75	4·75	3·50
	54	672	8·25	6·75	5·25	4·50	3·25
	56	627	7·75	6·25	5·00	4·00	3·00
	58	582	7·25	5·75	4·50	3·75	2·75
	60	537	6·75	5·25	4·25	3·50	2·50

Under-Trussed Beams.



See above; also see page 334 of maps for details. Breadth and depth of the upper piece may be determined from tables on pages 256 to 265, *i. e.*, take l. as span, and then opposite this span and in the columns of the given central spacing are given the breadth and depth of the beam. Or in other words, in this truss, for the span L we take only the span *l.* The strut will have breadth and thickness, each equal to the breadth of upper piece.

The lower rod is generally round and made of steel, which should not be made to bear more than 5 tons per square inch section; and the following table has been calculated accordingly.

Use of the tables.—Multiply the weight per square foot of roof by spacing of trusses from centre to centre. In the column of this product and opposite span L is given the diameter of rod.

Example.—Spacing from centre to centre is 8′, weight per square foot of roof is 125 lb.; if the length of truss be 20′ and depth 2′, find out the diameter of steel rod.

Weight per foot run $=125\times 8=1{,}000$.

Depth $=2'=\frac{20}{10}=\frac{\text{span}}{10}$, and span 20′. In the table below opposite to span 20 and in the column of 1,000 lb. (last column in the table) is given 2·33 as sectional area and $1\frac{3}{4}''$ as diameter of the rod.

Table of Tie Rod required for Under-trussed Beams, when Depth of truss $=\frac{\text{span}}{10}$.

Span in feet.	Weight per foot run = weight distributed per square foot × spacing centre to centre.													
	400 lb.		500 lb.		600 lb.		700 lb.		800 lb.		900 lb.		1,000 lb.	
	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.
Ft.	s. in	In.	s. in.	In.	s. in	In.	s. in.	In	s. in.	In.	s. in.	In	s. in.	In.
16	·74	1	·93	1 1/8	1·12	1 1/4	1·30	1 5/16	1·49	1 3/8	1·68	1 1/2	1 86	1 9/16
17	·79	1	·99	1 1/8	1·18	1 1/4	1·38	1 3/8	1·57	1 7/16	1·78	1 9/16	1·98	1 5/8
18	·84	1 1/16	1·05	1 3/16	1·26	1 5/16	1·46	1 3/8	1·68	1 1/2	1 89	1 9/16	2·10	1 11/16
19	·89	1 1/16	1·10	1 3/16	1·33	1 5/16	1·55	1 7/16	1·77	1 9/16	1·99	1 5/8	2·22	1 11/16
20	·93	1 1/8	1·17	1 1/4	1·40	1 3/8	1·63	1 1/2	1·86	1 9/16	2·10	1 11/16	2·33	1 3/4
21	·98	1 1/8	1·22	1 1/4	1·46	1 3/8	1·71	1 1/2	1·96	1 5/8	2·20	1 11/16	2·45	1 13/16
22	1·02	1 3/16	1·28	1 5/16	1·54	1 7/16	1·79	1 9/16	2·05	1 5/8	2·30	1 3/4	2·56	1 13/16
23	1·07	1 3/16	1·34	1 5/16	1·61	1 7/16	1 87	1 9/16	2·14	1 11/16	2·41	1 13/16	2·68	1 7/8
24	1·12	1 1/4	1·40	1 3/8	1·68	1 1/2	1·96	1 5/8	2·24	1 3/4	2·51	1 13/16	2·80	1 15/16
25	1·17	1 1/4	1·46	1 3/8	1 74	1 1/2	2·04	1 5/8	2·33	1 3/4	2·62	1 7/8	2·91	1 15/16
26	1·21	1 1/4	1·51	1 7/16	1·82	1 9/16	2·12	1 11/16	2·42	1 13/16	2·73	1 7/8	3·03	2
27	1·26	1 5/16	1·56	1 7/16	1·89	1 9/16	2·20	1 11/16	2·52	1 13/16	2·83	1 15/16	3·15	2 1/16
28	1·30	1 5/16	1·63	1 1/2	1·96	1 5/8	2·28	1 3/4	2·61	1 7/8	2·94	1 15/16	3·26	2 1/16
29	1·35	1 5/16	1·69	1 1/2	2·02	1 5/8	2·37	1 3/4	2·70	1 7/8	3·04	2	3·38	2 1/8
30	1·40	1 3/8	1·74	1 1/2	2·10	1 11/16	2·45	1 13/16	2·79	1 15/16	3·14	2	3·50	2 1/8

NOTE.—Sectional area is calculated for steel at 5 tons per square inch, tension; in case of iron where 4 tons only is allowed, take $\frac{5}{4}$ of the area given above, and find the corresponding diameter.

Table of Tie Rod required for Under-trussed Beams, when Depth of truss $= \frac{\text{span}}{12}$

Span in feet.	Weight per foot run = weight distributed per square foot × spacing centre to centre.													
	400 lb.		500 lb.		600 lb.		700 lb		800 lb		900 lb		1,000 lb.	
	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.
Ft.	s. in.	In.	s. in.	In.	s. in.	In.	s. in.	In	s. in.	In.	s. in.	In	s. in.	In.
16	·89	1 1/16	1·11	1 3/16	1·34	1 5/16	1·56	1 7/16	1·78	1 9/16	2·01	1 5/8	2·22	1 11/16
17	·94	1 1/8	1·18	1 1/4	1·42	1 3/8	1·66	1 1/2	1·90	1 9/16	2·13	1 11/16	2·36	1 3/4
18	1·00	1 1/8	1·25	1 5/16	1·50	1 7/16	1·75	1 1/2	2·01	1 5/8	2·26	1 3/4	2·50	1 13/16
19	1·06	1 3/16	1·32	1 5/16	1·59	1 7/16	1·86	1 9/16	2·12	1 11/16	2·38	1 3/4	2·65	1 7/8
20	1·11	1 3/16	1·39	1 3/8	1·67	1 1/2	1·95	1 5/8	2·23	1 11/16	2·50	1 13/16	2·79	1 15/16
21	1·17	1 1/4	1·46	1 3/8	1·75	1 1/2	2·05	1 5/8	2·35	1 3/4	2·63	1 7/8	2·93	1 15/16
22	1·22	1 1/4	1·53	1 7/16	1·84	1 9/16	2·14	1 11/16	2·46	1 13/16	2·76	1 7/8	3·07	2
23	1·28	1 5/16	1·60	1 7/16	1·92	1 9/16	2·24	1 11/16	2·56	1 13/16	2·89	1 15/16	3·21	2 1/16
24	1·34	1 5/16	1·67	1 1/2	2·01	1 5/8	2·34	1 3/4	2·67	1 7/8	3·01	2	3·35	2 1/8
25	1·39	1 3/8	1·74	1 1/2	2·09	1 11/16	2·44	1 13/16	2·78	1 15/16	3·14	2	3·48	2 1/8
26	1·45	1 3/8	1·81	1 9/16	2·17	1 11/16	2·54	1 13/16	2·90	1 15/16	3·26	2 1/16	3·62	2 3/16
27	1·50	1 7/16	1·88	1 9/16	2·26	1 3/4	2·63	1 7/8	3·01	2	3·38	2 1/8	3·76	2 3/16
28	1·56	1 7/16	1·95	1 5/8	2·34	1 3/4	2·73	1 7/8	3·12	2	3·51	2 1/8	3·90	2 1/4
29	1·62	1 7/16	2·02	1 5/8	2·42	1 13/16	2·83	1 15/16	3·23	2 1/16	3·63	2 3/16	4·04	2 5/16
30	1·67	1 1/2	2·10	1 11/16	2·50	1 13/16	2·93	1 15/16	3·34	2 1/16	3·76	2 3/16	4·18	2 5/16

NOTE.—Sectional area is calculated for steel at 5 tons per square inch, tension in case of iron where 4 tons only is allowed, take ¾ of the area given above, and find the corresponding diameter.

Table of Tie Rod required for Under-trussed Beams, when Depth of truss = $\frac{\text{span}}{14}$

Weight per foot run = weight distributed per square foot × spacing centre to centre.

	400 lb.		500 lb.		600 lb.		700 lb.		800 lb.		900 lb.		1,000 lb.	
	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.
Ft.	s. in.	In.	s. in.	In.	s. in.	In.	s. in.	In.	s. in.	In.	s. in.	In.	s. in.	In.
16	1·02	1 3/16	1·28	1 5/16	1·54	1 7/16	1·79	1 9/16	2·04	1 5/8	2·28	1 3/4	2·55	1 13/16
17	1·09		1·36	1 3/8	1·63	1 1/2	1·90	1 9/16	2·17	1 11/16	2·42	1 13/16	2·71	1 7/8
18	1·15		1·44	1 3/8	1·73	1 1/2	2·01	1 5/8	2·30	1 3/4	2·57	1 13/16	2·86	1 15/16
19	·22		1·52	1 7/16	1·82	1 9/16	2·12	1 11/16	2·42	1 13/16	2·71	1 7/8	3·02	2
20	·28		1·60	1 7/16	1·91	1 9/16	2·23	1 11/16	2·55	1 13/16	2·86	1 15/16	3·18	2 1/16
21	·34	1 5/16	1·67	1 1/2	2·01	1 5/8	2·34	1 3/4	2·68	1 7/8	3·00	2	3·34	2 1/16
22	·41	1 3/8	1·75	1 1/2	2·10	[illegible]	2·46	1 13/16	2·81	1 15/16	3·14	2	3·50	2 1/8
23	·47	1 3/8	1·83	1 9/16	2·20	1 11/16	2·57	1 13/16	2·94	1 15/16	3·28	2 1/16	3·66	2 3/16
24	·54	1 7/16	1·91	1 9/16	·30	1 3/4	2·68	1 7/8	3·06		3·42	2 1/8	3·82	2 1/4
25	·60	1 7/16	1·99		2·39	1 3/4	2·79	1 15/16	3·19	2 1/16	3·57	2 3/16	·98	2 1/4
26	·66	1 1/2	·07	1 5/8	2·49		2·90	1 15/16	3·32	2 1/16	3·70	2 3/16	4·14	2 5/16
27	·73	1 1/2	·15	1 11/16	2·58		3·02	2	3·45	2 1/8	3·85	2 1/4	4·30	[illegible]
28	79	1 9/16	·23		2·68		3·13	2	3·58	2 3/16	3·99	2 5/16	4·46	2 7/16
29	·86	1 9/16	·31		2·78		3·24	2 1/16	3·70	2 3/16	4·14	2 5/16	4·62	2 7/16
30	·92	1 9/16	2·39	1 3/4	2·87		3·35	2 1/8	3·83	2 1/4	4·28	2 3/8	4·78	2 1/2

Note.—Sectional area is calculated for steel at 5 tons per square inch tension; in case of iron where 4 tons only is allowed, take $\frac{5}{4}$ of the area given above, and find the corresponding diameter.

Table of Tie Rod required for Under-trussed Beams, when Depth of truss $= \frac{\text{span}}{16}$.

Span in feet.	400 lb.		500 lb.		600 lb.		700 lb.		800 lb.		900 lb.		1000 lb.	
	Weight per foot run = weight distributed per square foot × spacing centre to centre.													
	Sectional area.	Nearest diam.	Sectional area	Nearest diam	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.	Sectional area.	Nearest diam.
Ft.	s. in	In.	s. in.	In.	s. in	In	s. in.	In.	s. in.	In.	s. in.	In.	s. in	In.
16	1·16	1 1/4	1·46	1 3/8	1·74	1 1/2	2·03	1 5/8	2·33	1 3/4	2·62	1 7/8	2·91	1 15/16
17	1·23	1 1/4	1·54	1 7/16	1·85	1 9/16	2·16	1 11/16	2·48	1 13/16	2·78	1 15/16	3·10	2
18	1·31	1 5/16	1·63	1 1/2	1·96	1 5/8	2·29	1 3/4	2·62	1 7/8	2·94	1 15/16	3·28	2 1/16
19	1·38	1 3/8	1·73	1 1/2	2·07	1 5/8	2·42	1 13/16	2·77	1 15/16	3·10	2	3·46	2 1/8
20	1·46	1 3/8	1·82	1 9/16	2·18	1 11/16	2·54	1 13/16	2·91	1 15/16	3·27	2 1/16	3·64	2 3/16
21	1·53	1 7/16	1·90	1 9/16	2·29	1 3/4	2·67	1 7/8	3·06	2	3·43	2 1/8	3·82	2 1/4
22	1·60	1 7/16	2·00	1 5/8	2·40	1 3/4	2·80	1 15/16	3·21	2 1/16	3·60	2 3/16	4·01	2 5/16
23	1·67	1 1/2	2·09	1 11/16	2 50	1 13/16	2·93	1 15/16	3·35	2 1/8	3·76	2 3/16	4·19	2 5/16
24	1·74	1 1/2	2·18	1 11/16	2·62	1 7/8	3·05	2	3·50	2 1/8	3·92	2 1/4	4·37	2 3/8
25	1·82	1 9/16	2·27	1 3/4	2·73	1 7/8	3·18	2 1/16	3·64	2 3/16	4·09	2 5/16	4·55	2 7/16
26	1·89	1 9/16	2·36	1 3/4	2·83	1 15/16	3 30	2 1/16	3·78	2 1/4	4·25	2 3/8	4·74	2 1/2
27	1·96	1 5/8	2·45	1 13/16	2·94	1 15/16	3·43	2 1/8	3·93	2 1/4	4·42	2 3/8	4·92	2 9/16
28	2·03	1 5/8	2·54	1 13/16	3 05	2	3·56	2 3/16	4·08	2 5/16	4·58	2 7/16	5·10	2 9/16
29	2·10	1 11/16	2·63	1 7/8	3·16	2 1/16	3·69	2 3/16	4·22	2 3/8	4·74	2 1/2	5·28	2 5/8
30	2·18	1 11/16	2·73	1 7/8	3·26	2 1/16	3·82	2 1/4	4·37	2 3/8	4·90	2 1/2	5·46	2 11/16

Note.—Sectional area is calculated for steel at 5 tons per square inch tension; in case of iron where 4 tons only is allowed, take 5/4 of the area given above, and find the corresponding diameter.

TRUSSED BEAMS.

When the span exceeds 22′, it is usual and necessary to strengthen the beams by trussing.

Let W = distributed weight.

L = span of truss.

l = distance of tie or strut from nearest point of support.

D = depth of the truss.

A = angle of inclined portion with horizontal.

S = strain on centre of horizontal part of top and bottom.

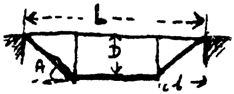
s = strain on inclined portion.

w = Load concentrated over each vertical for single truss.



Single truss :— $S = \frac{WL}{8\,D} = \frac{W}{4}$ Cot A.

$s = S\frac{\sqrt{L^2 \times (2D)^2}}{L} = \frac{W}{4}$ Co-sect A.



Queen truss :— $S = \frac{Lw}{D}$; $s = S\frac{\sqrt{L^2 + D^2}}{L} = S \times$ Sec. A.

Example.—Beam 30′ long and the strut 4′ long in the middle. Calculate the sizes of deodar beams placed 5′ apart from c to C and that of tie rod to be used in making it.

Weight of roof covering = 100 lbs. per sq. foot.

$W = 30 \times 5 \times 100 = 15000$ lbs.

$L = 30'$; $D = 4'$

$S = \frac{WL}{8\,D} = \frac{15000 \times 30}{8 \times 4} = 14063$ lbs.

Unsupported length of beam = 15′

Take 700 lbs. per sq. foot. as safe crushing.

Strain of Deodar. Sectional area of beam $= \frac{2 \times 14063}{700} = 40$ sq. inches.

Assume $b = \frac{2}{3}d$

$\frac{2}{3}d^2 = 40 \qquad d = 7{\cdot}75$

$b = 5{\cdot}16$

Use 5″ × 8″ beam.

5″ × 5″ strut.

$$s = S\frac{\sqrt{L^2 + (2D)^2}}{L} = \frac{14063\sqrt{900 + 64}}{30}$$

= 15000 lbs. sq. inch.

Safe tensile stress of wrought iron = 4 tons per sq. inch.

$\therefore$ Area required $= \dfrac{15000}{4 \times 2240} = 167$ sq. inches.

Use $1\frac{1}{2}''$ bar when sectional area $= 1{\cdot}67$ sq. inches.

Flitched Beams :—

It is a compound beam, *i. e.*, timber reinforced with steel and the whole acts as one piece. The plate is always placed symetrically with the beam, sometimes channel iron is used

Let

d_i = depth of iron plate.

d_t = depth of timber.

f_i = safe stress of steel in lbs. per sq. inch.

f_t = safe stress of timber in lbs. per sq. inch.

E_t = Elastic modulus of timber

E_i = Do. do. steel.

Then $\dfrac{d_i}{d_t} = \dfrac{f_i \; E_t}{F_t \; E_i}$ ——————(1)

Suppose $f : F_t :: 10 : 1$.

$E_i : E_t :: 20 : 1$.

Then $\dfrac{d_i}{d_t} = \dfrac{10}{20} = \frac{1}{2}$ ——————(2)

Or depth of iron plate $= \frac{1}{2}$ depth of joist

Also Moment of Resistance of Combination. = sum of the moments of resistance of compound parts.

Example.—A flitched beam consists of 2, $12'' \times 4''$ timber joists with one $8'' \times \frac{3}{4}$ steel flitched plate, placed symmetrically between them The whole being rigidly bolted together and freely supported on a 20 ft. span. If the stress in the timber does not exceed 1000 lbs. per sq. inch. and the stretch modulii 20, calculate (*a*). The Max uniformly distributed load the beam will carry.

(*b*) The Max. stress set up in the steel when the beam is carrying the load.

From equation (1) $f_i = \dfrac{d_i.\ ft.\ E_i}{E_t.\ d_c} = \dfrac{4 \times 100 \times 20}{6} = 13333$ lbs. per sq. inch.

M. R of steel $= f_i z = 13333 \times \dfrac{\frac{3}{4} \times 8^2}{6} = 106664$ in lbs.

M. R. of timber $= 2\ f_t z = 2 \times 1000 \times \dfrac{4 \times 144}{6} = 192000$ in lbs.

M. R., ... Total $= 298664$ in lbs.

M. R. = Bending moment.

$$B. M. = \frac{WL^2}{8} = \frac{W \times 20 \times 20 \times 12}{8}$$

$$\therefore 298664 = \frac{W \times 20 \times 20 \times 12}{8}$$

Total load = 20 × 498 = 9960 lbs. and W = 498 lbs. per ft. run.

Flitched Beam, 2nd method :—

Let

L = span in ft.

b = breadth of beam in inches.

b_s = breadth of steel plates.

d = depth of beam in inches.

W = total load.

$$\text{M. R. of combination} = \frac{bd^2f}{6} + \frac{b_s d^2 f_s}{6}$$

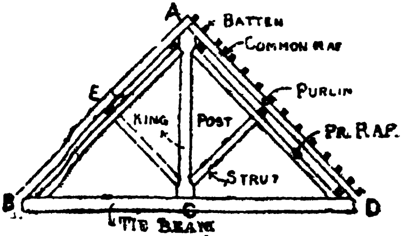
$$= \frac{bd^2}{6} f + \frac{b_s d^2}{6} \times 20 f.$$

$$= \frac{d^2}{6} f \left(b + 20 b_s\right) \text{——( )}$$

Also Bending moment = moment of Resistance.

Weight to be taken for Calculation in Trussed Roofs.

Description of Roof covering.	LOAD IN LBS. PER SQ. FT.						
			Trusses Rafter Purlins.	*Total Dead Load.*	*Total Dead Load.*	*Wind Load.*	Total load for design.
	Vertical.	Normal.	Vertical.	Vertical.	Normal.	Normal.	Normal for Roof covering vertical for trusses.
Corrugated iron or Nani Tal pattern	3	3	2	5	5	17	22
Single Mangalore Tiles or Slates ..	10	9	3	13	12	14	26
Single Country Tiles	14	13	4	16	16	13	19
Single Smith Tiles	14	13	4	18	16	13	29
SIALKOT PATTERN							
Single Allahbad Tiles ..	17	15	4	21	19	12	30
Double Country Tiles ..	24	22	5	29	26	11	32
Double Smith Tiles	29	26	6	35	31	10	41
Double Allahbad Tiles ..	34	31	6	40	38	10	40



Dimensions of battens, common rafters, and purlins can be calculated according to the table of karies given on pages 248-255 *i.e.*, take them as karies or beams. Take the weight as in the above table.

Now to consider each piece of the truss.

Roofs have either a slope of 1 in 1 *i.e.*, AC=BC (an angle of 45°); or 1 in 2.

i. e., $AC=\frac{BC}{2}$ (angle of 26° ·35′).

The above table gives weights for each of these slopes.

Principal Rafter.—If the truss is made of wood, calculate Principal Rafter from tables on pages 256-265 of beams, taking AE as span. But in that table, the ratio of breadth to depth has been assumed equal to ½ whereas in trusses, it is generally taken equal to ⅝. Therefore on pages 283-284 are given fresh tables for the same. On pages 285 287 are tables suiting a special kind of roof. If, on the other hand, the truss is made of iron, the necessary dimensions of T or angle iron required may be calculated according to the table given on pages 113-115.

Tie Beams.—In a wooden truss, it is generally of the same scantlings, as the Principal Rafter. If the Tie Beam is of iron, or steel, find its diameter from table on pages 281-282 which is for round steel and is calculated at 5 tons per square inch. For 4 tons per square inch, divide the strain given by 4×2240 or 8960 lb. The result is the area of section of rod; from which calculate diameter of the rod, as in table on page 56.

Strut.—If of wood, to be of the same scantlings, as the breadth of the Principal Rafter; for instance, if the Principal Rafter is 4″×6″, the strut would be 4″×4″.

King-post.—If of wood, to be equal to strut; but the head and foot to be wider for jointing.

The following table will be found useful in calculating the weight of roof:—

Average Weights of Building Materials.

Material.	Weight per c. ft.	Material.	Weight per s. ft.
	lb.		
Brickwork in lime mortar	110-120	Tiles, single country ..	12¼
		,, double ,, ..	24
		,, Manglore ..	9-10
Earth ..	85-90	Floor dwelling-house ..	12-20
Concrete ..	120—150	,, Public rooms ..	25-30
Masonry Lime Stone ..	130—150	,, Ware-house ..	50—70
,, Granite ..	144—170	Crowd of persons ..	84
Teak Wood ..	52		
Sal ,, ..	62		
Chir ,, ..	40		



Table of DIAMETERS OF TIE RODS *in King post Trusses under different Loads, when Slope of Roof is* 1 *to* 1.

NOTE.—Diameter is calculated at 5 tons per square inch.

Span.	Loads per foot run = weight per s. ft. × spacing c to c.									
	400 lb.		450 lb.		500 lb.		550 lb.		600 lb.	
	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.
Ft.	lb.	Inches.	lb.	Inches.	lb.	Inches.	lb.	Inches.	lb.	Inches.
16	3400	$\frac{5}{8}$	3825	$\frac{11}{16}$	4250	$\frac{3}{4}$	4675	$\frac{3}{4}$	5100	$\frac{13}{16}$
17	3600	$\frac{11}{16}$	4050	$\frac{11}{16}$	4500	$\frac{3}{4}$	4950	$\frac{3}{4}$	5400	$\frac{13}{16}$
18	3800	$\frac{11}{16}$	4300	$\frac{3}{4}$	4775	$\frac{3}{4}$	5250	$\frac{13}{16}$	5750	$\frac{13}{16}$
19	4050	$\frac{11}{16}$	4550	$\frac{3}{4}$	5050	$\frac{13}{16}$	5550	$\frac{13}{16}$	6050	$\frac{7}{8}$
20	4250	$\frac{3}{4}$	4775	$\frac{3}{4}$	5300	$\frac{13}{16}$	5850	$\frac{5}{8}$	6400	$\frac{7}{8}$
21	4450	$\frac{3}{4}$	5000	$\frac{3}{4}$	5600	$\frac{13}{16}$	6150	$\frac{7}{8}$	6700	$\frac{7}{8}$
22	4675	$\frac{3}{4}$	5250	$\frac{13}{16}$	5850	$\frac{7}{8}$	6450	$\frac{7}{8}$	7000	$\frac{15}{16}$
23	4900	$\frac{3}{4}$	5500	$\frac{13}{16}$	6100	$\frac{7}{8}$	6700	$\frac{7}{8}$	7350	$\frac{13}{16}$
24	5100	$\frac{13}{16}$	5750	$\frac{13}{16}$	6100	$\frac{7}{8}$	7000	$\frac{15}{16}$	7650	$\frac{15}{16}$
25	5300	$\frac{13}{16}$	6000	$\frac{7}{8}$	6600	$\frac{7}{8}$	7300	$\frac{15}{16}$	8000	1
26	5500	$\frac{13}{16}$	6200	$\frac{7}{8}$	6900	$\frac{15}{16}$	7600	$\frac{15}{16}$	8300	1
27	5700	$\frac{13}{16}$	6500	$\frac{7}{8}$	7200	$\frac{15}{16}$	7900	1	8600	1
28	6000	$\frac{7}{8}$	6700	$\frac{7}{8}$	7500	$\frac{15}{16}$	8200	1	8900	$1\frac{1}{16}$
29	6200	$\frac{7}{8}$	7000	$\frac{15}{16}$	7700	$\frac{15}{16}$	8500	1	9200	$1\frac{1}{16}$
30	6400	$\frac{7}{8}$	7200	$\frac{15}{16}$	8000	1	8800	1	9600	$1\frac{1}{16}$

Table of DIAMETERS OF TIE RODS *in King-post Trusses under different Loads, when Slope of Roo, is 2 to 1.*



NOTE.—Diameter is calculated at 5 Tons per square inch.

Span.	Loads per foot run=weight per s. ft. spacing c. to c.									
	400 lb.		450 lb.		500 lb.		550 lb.		600 lb.	
	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.	Strain.	Diameter of Tie Rod.
Ft.	lb.	Inches.	lb.	Inches.	lb.	Inches.	lb.	Inches.	lb.	Inches.
16	5400	$\frac{13}{16}$	6000	$\frac{7}{8}$	6700	$\frac{7}{8}$	7400	$\frac{15}{16}$	8100	1
17	5700	$\frac{13}{16}$	6400	$\frac{7}{8}$	7200	$\frac{15}{16}$	7900	1	8600	1
18	6000	$\frac{7}{8}$	6800	$\frac{15}{16}$	7600	$\frac{15}{16}$	8300	1	9100	$1\frac{1}{16}$
19	6400	$\frac{7}{8}$	7200	$\frac{15}{16}$	8000	1	8800	1	9600	$1\frac{1}{16}$
20	6700	$\frac{7}{8}$	7600	$\frac{15}{16}$	8400	1	9300	$1\frac{1}{16}$	10100	$1\frac{1}{8}$
21	7100	$\frac{15}{16}$	8000	1	8800	1	9700	$1\frac{1}{16}$	10600	$1\frac{1}{8}$
22	7400	$\frac{15}{16}$	8300	1	9200	$1\frac{1}{16}$	0200	$1\frac{1}{8}$	11100	$1\frac{1}{8}$
23	7700	$\frac{15}{16}$	8700	1	9600	$1\frac{1}{16}$	10600	$1\frac{1}{8}$	11600	$1\frac{3}{16}$
24	8100	1	9100	$1\frac{1}{16}$	10000	$1\frac{1}{8}$	11100	$1\frac{1}{2}$	12100	$1\frac{3}{16}$
25	8400	1	9400	$1\frac{1}{16}$	10500	$1\frac{1}{8}$	11600	$1\frac{3}{16}$	12600	$1\frac{1}{4}$
26	8800	1	9800	$1\frac{1}{16}$	11000	$1\frac{1}{8}$	12000	$1\frac{3}{16}$	13100	$1\frac{1}{4}$
27	9100	$1\frac{1}{16}$	10200	$1\frac{1}{8}$	11400	$1\frac{3}{16}$	12500	$1\frac{1}{4}$	13600	$1\frac{1}{4}$
28	9400	$1\frac{1}{16}$	10600	$1\frac{1}{8}$	11800	$1\frac{3}{16}$	13000	$1\frac{1}{4}$	14100	$1\frac{5}{16}$
29	9800	$1\frac{1}{16}$	11000	$1\frac{1}{8}$	12200	$1\frac{3}{16}$	13400	$1\frac{1}{4}$	14600	$1\frac{5}{16}$
30	10000	$1\frac{1}{4}$	11400	$1\frac{3}{16}$	12600	$1\frac{1}{4}$	13900	$1\frac{5}{16}$	15100	$1\frac{5}{16}$

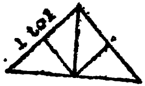


Table showing Dimensions of PRINCIPAL RAFTERS AND TIE BEAMS *under different Loads when Slope of Roof is* 1 *to* 1.

Span in feet.	Loads per foot run=weight per s. ft. × spacing c. to c.																			
	400 lb.				450 lb.				500 lb.				550 lb.				600 lb.			
	Deodar.		Sal or Teak.		Deodar.		Sal or Teak.		Deodar		Sal or Teak.		Deodar.		Sal or Teak.		Deodar.		Sal or Teak.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
16	4	6¼	3¼	5¼	4¼	6½	3½	5½	4¼	6½	3½	5½	4¼	6¾	3½	5¾	4½	7	3½	5¾
17	4	6½	3½	5½	4¼	6¾	3½	5¾	4½	7	3½	5¾	4½	7	3¾	6	4½	7¼	3¾	6
18	4¼	6¾	3½	5¾	4½	7	3¾	6	4½	7¼	3¾	6	4½	7¼	4	6¼	4¾	7½	4	6¼
19	4½	7	3¾	6	4½	7¼	3¾	6	4¾	7½	4	6¼	4¾	7½	4	6½	4¾	7¾	4	6½
20	4¾	7¼	4	6¼	4¾	7½	4	6½	4¾	7¾	4	6½	5	8	4¼	6¾	5¼	8¼	4½	7
21	4¾	7½	4¼	6½	4¾	7¾	4	6½	5	8	4¼	6¾	5¼	8¼	4½	7	5¼	8½	4½	7
22	5	8	4¼	6¾	5¼	8¼	4½	7	5¼	8½	4½	7	5¼	8½	4½	7¼	5½	8¾	4½	7¼
23	5¼	8¼	4½	7	5¼	8½	4½	7	5½	8¾	4½	7¼	5½	9	4¼	7½	5½	9	4¾	7½
24	5¼	8½	4½	7¼	5½	8¾	4¾	7¼	5½	9	4¾	7½	5¾	9¼	5	7¾	5¾	9¼	5	7¾
25	5½	8¾	4½	7¼	5¾	9	4¾	7½	5¾	9¼	5	7¾	6	9½	5	8	6	9½	5½	8
26	5¾	9	4¾	7½	5¾	9¼	5	7¾	6	9½	5	8	6¼	9¾	5¼	8¼	6¼	10	5¼	8¼
27	5¾	9¼	5	7¾	6	9½	5	8	6¼	9¾	5¼	8¼	6¼	10	5¼	8½	6½	10¼	5	8½
28	6	9½	5	8	6¼	9¾	5¼	8¼	6¼	10	5¼	8½	6½	10¼	5½	8¾	6½	10½	5½	9
29	6¼	9¾	5¼	8¼	6¼	10	5¼	8½	6½	10¼	5½	8¾	6½	10½	5½	8¾	6¾	10¾	5¼	9
30	6¼	10	5¼	8½	6½	10¼	5½	8¾	6½	10½	5½	9	6¾	10¾	5½	9	7	11	5¾	9¼



Table showing Dimensions of PRINCIPAL RAFTERS AND TIE BEAMS *under different Loads when Slope of Roof is 2 to 1.*

Span in feet.	Loads per foot run = weight per s. ft. × spacing c. to c.																			
	400 lb.				450 lb.				500 lb.				550 lb.				600 lb.			
	Deodar.		Sal or Teak.		Deodar.		Sal or Teak.		Deodar.		Sal or Teak.		Deodar.		Sal or Teak.		Deodar.		Sal or Teak.	
	b	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*	*b*	*d*
Ft.	ins.	ins.	ins.	ins	ins	ins	ins	ins	ins	ins.	ins	ins	ins.	ins.	ins	ins.	ins	ins.	ins	ins
16	3¼	5¼	2¾	4¼	3½	5½	2¾	4½	3½	5½	3	4¾	3½	5¾	3	4¾	3¾	6	3	5
17	3¼	5½	2¾	4½	3½	5¾	3	4¾	3¾	6	3	5	3¾	6	3	5	4	6¼	3¼	5¼
18	3½	5½	3	4¾	3¾	6	3	5	3¾	6	3	5	4	6¼	3¼	5¼	4	6¼	3¼	5¼
19	3½	5¾	3	5	4	6¼	3¼	5¼	4¼	6¼	3¼	5¼	4¼	6½	3½	5½	4¼	6½	3½	5½
20	3¾	6	3¼	5	4¼	6½	3½	5½	4¼	6½	3½	5½	4¼	6¾	3½	5¾	4¼	6¾	3½	5¾
21	4	6¼	3¼	5¼	4¼	6¾	3½	5¾	4½	7	3½	5¾	4½	7	3¾	6	4¾	7¼	3¾	6
22	4	6½	3½	5½	4½	7	3¾	5¾	4½	7¼	3¾	6	4½	7¼	4	6¼	4¾	7½	4	6¼
23	4¼	6¾	3½	5¾	4½	7¼	3¾	6	4¾	7¼	4	6¼	4¾	7½	4	6¼	5	7¾	4¼	6½
24	4½	7	3¾	5¾	4¾	7½	4	6¼	4¾	7½	4¼	6½	4¾	7¾	4¼	6½	5	8	4¼	6¾
25	4½	7¼	3¾	6	4¾	7¾	4	6½	5	7¾	4¼	6½	5	8	4¼	6¾	5¼	8¼	4½	7
26	4¾	7½	4¼	6½	5	7¾	4	6½	5	8	4¼	6¾	5¼	8¼	4½	7	5½	8½	4½	7
27	5	7¾	4¼	6½	5	8	4¼	6¾	5¼	8¼	4¼	7	5¼	8½	4½	7¼	5½	8¾	4½	7¼
28	5	8	4½	6¾	5¼	8¼	4½	7	5¼	8½	4⅛	7¼	5½	8¾	4¾	7¼	5¾	9	4¾	7½
29	5¼	8¼	4½	7	5¼	8½	4½	7¼	5½	8¾	4½	7¼	5¾	9	4¾	7½	5¾	9	5	7¾
30	5¼	8¼	4¼	7	5½	8¾	4½	7¼	5½	9	4¾	7½	5¾	9¼	4¾	7¾	6	9½	5	8

SCANTLINGS OF PRINCIPAL RAFTERS.

King-post Trusses of Sal and Teak; Double Allahabad Tiling.

Spacing c. to c.		Spans in Feet.								
		10′	12′	14′	16′	18′	20′	22′	24′	26′
Ft.	In.									
4	0	2×3	2½×3	2¼×3¼	2½×3¼	2½×3½	2¾×3¾	2¾×4	3×4	3×4¼
4	3	2¼×3	2½×3	2½×3¼	2½×3½	2¼×3½	2¾×4	3×4	3×4¼	3×4¼
4	6	2¼×3	2¼×3¼	2½×3¼	2¾×3½	2¾×3¾	3×3¾	3×4¼	3×4¼	3¼×4¼
4	9	2¼×3¼	2½×3¼	2½×3½	2¾×3¾	2¾×4	3×4	3×4¼	3¼×4¼	3¼×4¼
5	0	2¼×3¼	2½×3¼	2½×3¾	2¾×3¾	3×3¾	3×4¼	3¼×4¼	3¼×4½	3¼×4¾
5	3	2¼×3¼	2½×3½	2½×3¾	2¾×4	3×4	3¼×4¼	3¼×4½	3¼×4¾	3½×4¾
5	6	2½×3	2½×3½	2¾×3¾	3×4	3×4¼	3¼×4¼	3¼×4¾	3½×4¾	3½×5
5	9	2½×3¼	2½×3½	2¾×3¾	3×4	3¼×4	3¼×4½	3½×4½	3½×5	3½×5
6	0	2½×3¼	2¾×3½	2¾×4	3×4¼	3¼×4¼	3¼×4¾	3½×4¾	3½×5	3¾×5
6	3	2½×3½	2¾×3¾	3×4	3×4¼	3¼×4½	3½×4½	3½×5	3¾×5	3¾×5¼
6	6	2½×3½	2¾×3¾	3×4	3¼×4¼	3¼×4½	3½×4¾	3½×5	3¾×5¼	4×5¼
6	9	2¾×3½	3×3¾	3×4	3¼×4¼	3¼×4¾	3½×5	3¾×5	4×5	4×5¼
7	0	2¾×3½	3×3¾	3×4¼	3¼×4½	3½×4½	3½×5	3¾×5	4×5¼	4×5½
7	3	2¾×3½	3×4	3¼×4¼	3¼×4¾	3½×4¾	3¾×5	3¾×5¼	4×5½	4×5¾
7	6	2¾×3¾	3×4	3¼×4¼	3¼×4¾	3½×4¾	3¾×5	4×5¼	4×5¾	4¼×5½
7	9	2¾×3¾	3×4¼	3¼×4½	3½×4½	3½×5	3¾×5¼	4×5¼	4×5¾	4¼×5¾
8	0	2¾×4	3×4¼	3¼×4½	3½×4¾	3¾×5	4×5	4×5½	4¼×5¾	4¼×6

For Deodar multiply area of Section in above table by $\frac{1200}{700} = 1{\cdot}72.$

SCANTLINGS OF PRINCIPAL RAFTERS.

King-post Trusseg of Sal and Teak ; Single Allahabad Tiling.

Spacing c. to c.		Spans in Feet.								
		10′	12′	14′	16′	18′	20′	22′	24′	26′
Ft.	In.									
4	0	1¼×2¼	1½×2¼	1½×2½	1¾×2¾	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼
4	3	1½×2¼	1½×2½	1½×2¾	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2¼×3¼
4	6	1½×2¼	1½×2½	1¾×2¾	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2½×3¼
4	9	1½×2¼	1½×2¾	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2¼×3¼	2½×3¼
5	0	1½×2¼	1½×2¾	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3½
5	3	1½×2½	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3¼	2½×3½
5	6	1½×2½	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3½	2½×3¾
5	9	1½×2¾	1¾×2¾	2×3	2¼×3	2¼×3¼	2¼×3¼	2½×3½	2½×3¾	2¾×3½
6	0	1¾×2¾	2×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3½	2½×3¾	2¾×3¾
6	3	1¾×2¾	2×2¾	2×3	2¼×3¼	2¼×3¼	2½×3¼	2½×3¾	2¾×3½	2¾×3¾
6	6	1¾×2¾	2×2¾	2¼×3	2¼×3¼	2½×3¼	2½×3½	2½×3¾	2¾×3½	2¾×4
6	9	1¾×2¾	2×2¾	2¼×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3½	2¾×3¾	3×4
7	0	1¾×2¾	2×3	2¼×3	2¼×3¼	2½×3½	2½×3¾	2¾×3¾	2¾×4	3×4
7	3	1¾×2¾	2×3	2¼×3¼	2½×3¼	2½×3½	2¾×3½	2¾×3¾	2¾×4	3×4¼
7	6	2×2¾	2¼×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3½	2¾×4	3×4	3×4¼
7	9	2×2¾	2¼×3	2¼×3¼	2½×3⅛	2½×3¾	2¾×3¾	2¾×4	3×4	3¼×4¼
8	0	2×2¾	2¼×3	2¼×3¼	2½×3½	2¾×3½	2¾×3¾	3×4	3×4¼	3¼×4¼

For Deodar multiply area of Section in the above table by 1·72.

SCANTLINGS OF PRINCIPAL RAFTERS.

King-post Trusses of Teak ; Mangalore Tiling.

Spacing c. to c. Ft. In.	Spans in Feet. 10′	12′	14′	16′	18′	20′	22′	24′	26′
4 0	1½×2½	1¾×2½	1¾×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3¼	2½×3¾
4 3	1½×2¾	1¾×2¾	2×2¾	2×3	2¼×3¼	2½×3¼	2½×3¼	2½×3¾	2¾×3½
4 6	1¾×2½	1¾×2¾	2×2¾	2¼×3	2¼×3¼	2½×3¼	2½×3½	2½×3¾	2¾×3¾
4 9	1¾×2½	2×2¾	2×3	2¼×3¼	2½×3¼	2½×3¼	2½×3¾	2¾×3½	2¾×4
5 0	1¾×2½	2×2¾	2¼×3	2¼×3¼	2½×3¼	2½×3½	2¾×3½	2¾×4	3×3¾
5 3	1¾×2¾	2×3	2¼×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3¾	2¾×4	3×3¾
5 6	1¾×2¾	2×3	2¼×3¼	2½×3¼	2½×3½	2¾×3½	2¾×4	3×3¾	3×4
5 9	2×2¾	2¾×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3½	3×3¾	3×4	3×4¼
6 0	2×2¾	2¼×3	2½×3¼	2½×3¼	2¾×3½	2¾×4	3×3¾	3×4	3¼×4¼
6 3	2×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3½	2¾×4	3×4	3×4¼	3¼×4¼
6 6	2×3	2¼×3¼	2½×3¼	2½×3¾	2¾×3¾	3×3¾	3×4	3×4¼	3¼×4½
6 9	2¼×3	2¼×3¼	2½×3¼	2¾×3½	2¾×4	3×4	3×4¼	3¼×4¼	3¼×4¾
7 0	2¼×3	2½×3¼	2½×3½	2¾×3½	3×3¾	3×4	3¼×4¼	3¼×4½	3¼×4¾
7 3	2¼×3	2½×3¼	2½×3¾	2¾×4	3×3¾	3×4¼	3¼×4¼	3¼×4½	3½×4¾
7 6	2¼×3	2½×3¼	2½×3¾	2¾×4	3×4	3×4¼	3¼×4½	3¼×4¾	3½×4¾
7 9	2¼×3¼	2½×3¼	2¾×3½	3×3¾	3×4	3¼×4¼	3¼×4½	3¼×4¾	3½×5
8 0	2½×3¼	2½×3½	2¾×3½	3×3¾	3×4¼	3¼×4¼	3¼×4¾	3½×4¾	3½×5¼

NOTE.—For dimensions of Strap and Bolt at Foot of Principal Rafter and at the Head and Foot of King-post, see pages 288 and 289,

Strap and Bolt at Foot of Principal Rafters Double Allahabad Tiling.
King-post trusses of all kinds of timber.

Trusses c. to c.		Clear internal span.								
		10′	12′	14′	16′	18′	20′	22′	24′	26′
Ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4	0	$1\frac{1}{4} \times \frac{1}{4}$ $\frac{3}{4}$	$1\frac{1}{4} \times \frac{1}{4}$ $\frac{3}{4}$	$1\frac{1}{4} \times \frac{1}{4}$ 1	$1\frac{1}{4} \times \frac{1}{4}$ 1	$1\frac{1}{4} \times \frac{1}{4}$ 1	$1\frac{1}{4} \times \frac{1}{4}$ 1	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$
4	3	do.	do.	do.	do.	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{4}$
4	6	do.	$1\frac{1}{4} \times \frac{1}{4}$ 1	do.	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{4}$	do.
4	9	do.	do.	do.	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	do.	do.	do.
5	0	do.	do.	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{4}$	do.	do.
5	3	$1\frac{1}{4} \times \frac{1}{4}$ 1	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{4}$	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{3}{8}$
5	6	do.	do.	do.	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{4}$	do.
5	9	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{4}$	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{3}{8}$	do.
6	0	do.	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	do.	do.	$1\frac{1}{2} \times 1\frac{3}{8}$ $1\frac{1}{4}$	do.	do.
6	3	do.	do.	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{3}{8}$	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{2}$
6	6	do.	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{4}$	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{2}$	do.
6	9	do.	$1\frac{1}{4} \times \frac{1}{4}$ $1\frac{1}{8}$	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{3}{8}$	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{5}{8}$
7	0	do.	do.	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{2}$	do.	do.
7	3	do.	do.	$1\frac{1}{2} \times \frac{1}{4}$ $1\frac{1}{4}$	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{4}$	do.	do.	do.	$1\frac{3}{4} \times \frac{3}{8}$ $1\frac{5}{8}$
7	6	do.	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{3}{8}$	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{2}$	do.	do.	do.
7	9	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{1}{4}$	do.	do.	do.	$1\frac{1}{2} \times \frac{3}{8}$ $1\frac{5}{8}$	do.
8	0	do.	do.	do.	do.	do.	do.	do.	do.	do.

NOTE.—The dimensions of each limb of the strap are given above, and the diameter of the bolt below, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be $\frac{1}{8}$ inch less than those shown in the Table ; no bolt, however, being less than $\frac{1}{2}$ inch diameter.

STRAP AND BOLT *at foot of Principal Rafters Single Allahabad Tiling.*
King-post trusses of all kinds of timber.

Trusses c. to c.	Clear internal span.								
	10′	12′	14′	16′	18′	20′	22′	24′	26′
Ft. in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4 0	1¼×¼ ¾	¼×¼ ¾	1¼×¼ ¾	1¼×¼ ¾	1¼×¼ 1	1¼×¼ 1	1¼×¼ 1	1¼×¼ 1	1¼×¼ 1
4 3	do.	do.	do.	do.	do.	do.	do.	do.	1¼×¼ 1⅛
4 6	do.	do.	do.	1¼×¼ 1	do.	do.	do.	do.	do.
4 9	do.	do.	1¼×¼ 1	do.	do.	do.	do.	1¼×¼ 1⅛	do.
5 0	do.	do.	do.	do.	do.	do.	1¼×¼ 1⅛	do.	do.
5 3	do.	do.	do.	do.	do.	do.	do.	do.	1½×¼ 1¼
5 6	do.	do.	do.	do.	do.	1¼×¼ 1⅛	do.	do.	do.
5 9	do.	1¼×¼ 1	do.	do.	do.	do.	do.	1½×¼ 1⅛	do.
6 0	do.	do.	do.	do.	1¼×¼ 1⅛	do.	do.	do.	do.
6 3	do.	do.	do.	do.	do.	do.	1½×¼ 1¼	do.	do.
6 6	do.	do.	do.	do.	do.	do.	do.	do.	1½×⅜ 1¼
6 9	1¼×¼ 1	do.	do.	1¼×¼ 1⅛	do	1½×¼ 1¼	do.	do.	1½×⅜ 1⅜
7 0	do.	do	do.	do.	do.	do.	do.	1½×⅜ 1¼	do.
7 3	do.	do.	do.	do.	do.	do.	do.	1½×⅜ 1⅜	do.
7 6	do.	do.	do.	do.	1¼×¼ 1¼	do.	do.	do.	do.
7 9	do.	do.	1¼×¼ 1⅛	do.	do.	do.	1½×⅜ 1¼	do.	1½×⅜ 1½
8 0	do.	do.	do.	do.	do.	do.	1½×⅜ 1⅜	do	do.

NOTE.—The dimensions of each limb of the strap are given above, and the diameter of the bolt below, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be ½ inch less than those shown in the Table, no bolt however, being less than ½-inch diameter.

Average Weight of Roof and Side Coverings for 1,000 sq. ft. and minimum slopes for laying.

	Cwt.	Minimum slope.
Lead (5 to 8 lbs.)	.. $4\frac{3}{4}$ to $7\frac{1}{2}$	4°
Copper (·022″ thick)	.. 1	4°
Zinc (13 to 16 G)	.. $1\frac{1}{2}$ to $1\frac{3}{4}$	4°
Corrugated Sheets (22 to 28 G)	.. $1\frac{3}{4}$ to $3\frac{1}{2}$	10°
Slates	.. $5\frac{1}{2}$ to 9	21°
Tiles	.. 9 to 15	$26\frac{1}{2}$°
Boarding	.. 3	..
Asphalt felt	.. $\frac{1}{8}$	15°

Trignometrical Functions for Roof Slopes.

Slope.	Angle.	Sine.	Co-sine	Tangent.	Cot.	Secant.	Co-secant	Ratio of Rise to Span.
$\frac{1}{2}$ to 1	63·30	·89	·44	2·005	·49	2·24	1·11	1
$\frac{2}{3}$ to 1	56·20	·83	·55	1·50	·66	1·80	1·20	$\frac{3}{4}$
$\frac{3}{4}$ to 1	53·00	·79	·60	1·32	·75	1·66	1·25	$\frac{2}{3}$
1 in 1	45·00	·71	·71	1·00	1·00	1·41	1·41	$\frac{1}{2}$
2 in 3	33·41	·56	·83	·67	1·50	1·20	1·80	$\frac{1}{3}$
3 in 5	30·58	·52	·86	·60	1·67	1·17	1·94	$\frac{3}{10}$
1 in 2	26·34	·45	·89	·50	2·00	1·12	2·24	$\frac{1}{4}$
2 in 5	21·48	·37	·93	·40	2·50	1·08	2·09	$\frac{1}{5}$
1 in 3	18·26	·32	·[illegible]5	·33	3·00	1·05	3·16	$\frac{1}{6}$

Table showing dimensions of sal or teak king-post trusses for common tiled roof 10′ c to c to bear weight of 50 lb per sq. foot, slope 2 to 1.

Span ft.	Principal Rafter	Tie Beam.	King-post.	Struts.	Span ft.
16	4¾×3	5¼×3	3 ×3	3 ×3	16
17	5 ×3	5½×3	3½×3	3½×3	17
18	5 ×3	5½×3	3½×3	3½×3	18
19	5¼×3¼	6¼×3¼	3½×3¼	3½×3¼	19
20	5½×3½	6¼×3½	3½×3½	3½×3½	20
21	5¾×3½	6½×3½	3½×3½	3½×3½	21
22	6 ×3¾	7¼×3¾	3¾×3¾	3¾×3¾	22
23	6¼×4	7¼×4	4 ×4	4 ×4	23
24	6½×4¼	7½×4¼	4 ×4¼	4 ×4¼	24
25	6½×4¼	8 ×4¼	4¼×4¼	4¼×4¼	25
26	6¾×4¼	8¼×4¼	4½×4¼	4½×4¼	26
27	7 ×4¼	8½×4¼	4½×4¼	4½×4¼	27
28	7¼×4½	9 ×4½	4½×4½	4½×4½	28
29	7¼×4½	9 ×4½	4¾×4½	4¾×4½	29
30	7½×4¾	9 ×4¾	4¾×4¾	4¾×4¾	30

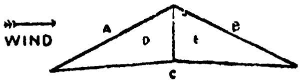
NOTE —For deodar multiply above section by 1·72.

Table showing dimensions of sal or teak queen-post trusses for common tiled roof 10′ c to c to bear weight of 50 lb per sq. foot, Rise ¼.

Span ft	Principal Rafter.	Tie Beam.	Struts.	Queen-posts.	Straining Beam.
32	6¾×5	7 ×3¾	5 ×3¾	3¾×3½	4¼×3¾
34	7 ×5	7¼×4	5 ×4	4 ×3½	4¼×4
36	7¼×5	7½×4	5 ×4	4 ×3¾	4½×4
38	7½×5	8 ×4	5 ×4	4 ×4	4½×4
40	7½×5¼	8¼×4¼	5¼×4	4 ×4	4¾×4
42	7¾×5½	8¾×4¼	5½×4¼	4¼×4	5 ×4¼
44	7¾×5¾	9 ×4½	5¾×4½	4½×4¼	5 ×4½
46	8 ×6	9¼×4½	6 ×4½	4½×4½	5½×4½

For deodar multiply above section by 1·72.

IRON ROOF TRUSSES.

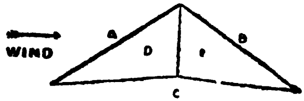


Rise of Rafter : · ¼th Span.
„ Main Tie = 1 in 15.

Stress Coefficients.

Dead Load. | Wind Pressure

mb	sic		Comp sion.		gth cie
A—D	·65		·45		·559
B—E	·65		·70		·559
C—D		·58		·49	·501
C—E		·58		·49	·501
D—E		·08		·07	·217



Rise ot Rafter = ⅓rd Span
„ Main Tie = 1 in 12.

Stress Coefficients.

Dead Load. Wind Pressure

	Compr sion.	Tension.	Comp sion.	nsion.	
A—D	·52		·25		·601
B—E	·52		·58		·601
-D		·43		·29	·502
C—E		·43		·29	·502
D—E		·07		·05	·292

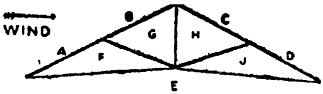


Fig. 2a.

Stress Coefficient.

Dead Load. | Wind Pressure

Member.	Compr sion.	Te	Comp sion.		Length C cient.
A—F	·97		1·05		·28(
D—J	·97		·70		·28(
B—G	·64		·57		·280
-H	·64		·70		·280
F—G	·31		·69		·266
H—J	·31		·00		·266
E—F		·87		1·13	·501
E—J		·87		·48	·501
G—H		·33		·34	217

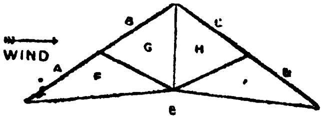


Fig. 2b

Stress Coefficients.

Dead Load. Wind Pressure

mb			m ior		Length Coe ient
	·77		·70		·300
	·77		·58		·300
	·51		·42		·300
	·51		·58		·300
	·24		·58		·28(
	·24		·00		·28C
		·65		·80	·502
		·65		·29	·502
(.—H		·32		·35	·292

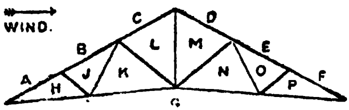


Fig. 3*a*.
Rise of Rafter = ¼th Span.
,, Main Tie = 1 in 15.

Member.	Stress Coefficient. Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—H	1·08		1·24		·186
F—P	1·08		·70		·186
B—J	·94		1·10		·186
E—O	·94		·70		·186
C—L	·65		·62		·186
D—M	·65		·70		·186
H—J	·17		·37		·107
O—P	·17		·00		·107
K—L	·25		·55		·214
M—N	·25		·00		·214
G—H		·96		1·35	·251
G—P		·96		·48	·251
G—K		·77		·92	·251
G—N		·77		·48	·251
J—K		·13		·30	·171
N—O		·13		·00	·171
L—M		·41		·44	·217

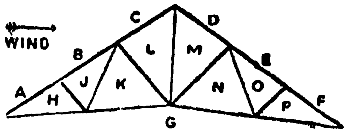
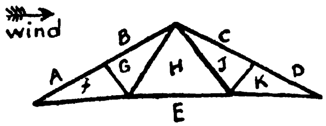


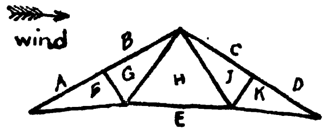
Fig. 3*b*.
Rise of Rafter = ⅓rd Span.
,, Main = 1 in 12.

Member.	Stress Coefficient. Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—H	·86		·86		·200
F—P	·86		·58		·200
B—J	·74		·80		·200
E—O	·74		·58		·200
C—L	·51		·47		·200
D—M	·51		·58		·200
H—J	·14		·34		·123
O—P	·14		·00		·123
K—L	·21		·51		·246
M—N	·21		·00		·246
G—H		·72		·98	·251
G—P		·72		·29	·251
G—K		·57		·63	·251
G—N		·57		·29	·251
J—K		12		·30	·218
N—O		12		·00	·218
L—M		40		·45	·292



Rise of Rafter =¼th Span.
„ Main Tie=1 in 15.

Member.	Stress Coefficient. Dead Load. Compression.	Stress Coefficient. Dead Load. Tension.	Stress Coefficient. Wind Pressure. Compression.	Stress Coefficient. Wind Pressure. Tension.	Length Coefficient.
A—F	·97		1·05		·279
D—K	·97		·70		·279
R—G	·85		1·05		·279
C—J	·85		·70		·279
F—G	·22		·50		·117
J—K	·22		·00		·117
E—F		·87		1·18	·302
E—K		·87		·48	·302
E—H		·54		·46	·395
G—H		·34		·69	·302
H—J		·35		·00	·302



Rise of Rafter =⅓rd Span.
„ Main Tie=1 in 12.

Member.	Stress Coefficient. Dead Load. Compression.	Stress Coefficient. Dead Load. Tension.	Stress Coefficient. Wind Pressure. Compression.	Stress Coefficient. Wind Pressure. Tension.	Length Coefficient.
A—F	·77		·70		·300
D—K	·77		·58		·300
B—G	·63		·70		·300
C—J	·63		·58		·300
F—G	·21		·50		·166
J—K	·21		·00		·166
E—F		·65		·80	·343
E—K		·65		·29	·343
E—H		·41		·28	·317
G—H		·26		·54	·343
H—J		·26		·23	·343

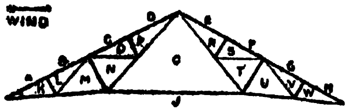


Fig. 5a

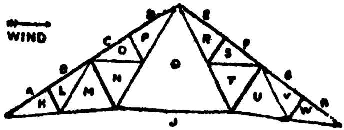


Fig. 5b.

Rise of Rafter =¼th Span.
„ Main Tie=1 in 15.

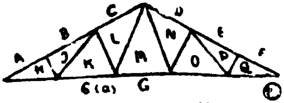
Stress Coefficients.

Member.	Dead Load. Compression	Dead Load. Tension	Wind Pressure. Compression.	Wind Pressure. Tension	Length Coefficient
A—K	1·13		1·34		·14(
H—W	1·13		·70		·14(
B—L	1·07		1·34		·14(
G—V	1·07		·70		·14(
C—O	1·02		1·34		·14(
F—S	1·02		·70		·14(
D—P	·96		1·34		·14(
E—R	·96		·70		·14(
M—N	·22		·50		·11
T—U	·22		·00		·11
K—L O—P	·11		·25		·059
V—W R—S	·11		·00		·059
J—K		1·01		1·46	·152
J—W		1·01		·48	·152
J—M		·87		1·13	·15:
J—U		·87		·48	·15:
J—Q		·54		·45	·395
—N		·34		·69	152
Q—T		·34		·04	152
Q—P		·49		1·01	152
Q—R		·49		·04	152
L—M N—O		·15		·32	152
U—V S—T		·15		·00	152

Rise of Rafter =⅓rd Span.
„ Main Tie=1 in 12.

Stress Coefficients.

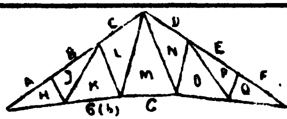
Mem	Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—K	.90		·93		·15
H—V	·90		·58		·150
B—L	·83		·93		·150
G—V	·83		·58		·150
—O	·76		·93		·150
F—S	·76		·58		·150
D—P	·69		·93		·150
E—R	·69		·58		·150
M—N	·21		·50		·166
T—U	·21		·00		·16
K—L O—P	·10		·25		·083
V—W R—S	·10		·00		·083
J—K		·75		1 06	·171
—W		·75		·29	·171
—M		·64		·81	·171
—U		·64		·29	·171
—Q		·41		·28	·317
Q—N		·26		·55	·171
—T		·26		·03	·171
Q—P		·36		·80	·171
Q—R		·36		·03	·171
L—M N—O		·11		·26	·171
U—V S—T		·11		·00	·171



6(a) G

RISE OF RAFTER = 1/4 SPAN
RISE OF MAIN TIE = 1 IN 15

Member.	Stress Coefficients. Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—B	1 08		1·24		·186
F—Q	1·08		·70		·186
B—J	1·00		1·24		·186
E—P	1·00		·70		·186
C—L	·75		·85		·186
D—N	·75		·70		·186
H—J	·15		·33		·078
P—Q	·15		·00		·078
R—L	·22		·50		·155
N—O	·22		·00		·155
G—H		.96		1·35	·200
G—Q		.96		.48	·200
G—R		.77		·92	·200
G—O		.77		·42	·200
G—M		.56		·47	·200
J—K		.59		·43	·203
O—P		.29		·00	·203
L—M		.27		·55	·245
M—N		.27		·04	·245



6(b) C

RISE OF RAFTER = 1/3 SPAN
RISE OF MAIN TIE = 1 IN 12.

Member.	Stress Coefficients. Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—H	·86		·86		·200
F—Q	·86		·58		·200
B—J	·81		·94		·200
E—P	·81		·58		·200
C—L	·60		·68		·200
D—N	·60		·58		·200
H—J	·14		·34		·100
P—U	·14		·00		·100
K—L	·22		·52		·200
H—O	·22		·00		·200
G—H		·72		·98	·201
G—Q		·72		·29	·201
G—K		·58		·63	·201
G—O		·58		·29	·201
G—M		·42		·28	·201
J—K		·18		·42	·245
O—P		·18		·00	·245
L—M		·26		·57	·317
M—N		·26		·03	·317

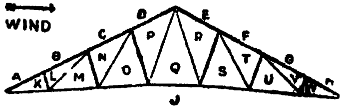


Fig 7a.

Rise of Rafter = $\frac{1}{4}$th Span.
Rise of Main Tie = 1 in 15.

Member.	Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—K	1·13		1·34		·140
H—W	1·13		·70		·140
B—L	1·09		1·38		·140
G—V	1·09		·70		·140
C—N	·90		1·09		·140
F—T	·90		·70		·140
D—P	·72		·82		·140
E—R	·72		·70		·140
K—L	·11		·25		·056
V—W	·11		·00		·056
M—N	·17		·38		·112
T—U	·17		·00		·112
O—P	·22		·51		·168
R—S	·22		·00		·168
J—K		1·01		1·46	·143
J—W		1·01		·48	·143
J—M		·87		1·13	·143
J—U		·87		·48	·143
J—O		·72		·81	·143
J—S		·72		·48	·143
J—Q		·57		·47	·143
L—M		·16		·36	·158
U—V		·16		·00	·158
N—O		·19		·43	·191
S—T		·19		·00	·191
P—Q		·27		·56	·233
Q—R		·27		·03	·233

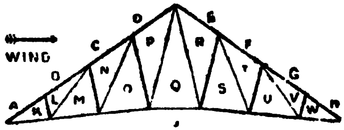


Fig. 7b.

Rise of Rafter = $\frac{1}{3}$rd Span.
Rise of Main Tie = 1 in 12.

Member.	Dead Load. Compression.	Dead Load. Tension.	Wind Pressure. Compression.	Wind Pressure. Tension.	Length Coefficient.
A—K	·90		·93		·150
H—W	·90		·58		·150
B—L	·87		1·02		·150
G—V	·87		·58		·150
C—N	·72		·84		·150
F—T	·72		·58		·150
D—P	·58		·66		150
E—R	·58		·58		·150
K—L	·11		·27		·074
V—W	·11		·00		·074
M—N	·17		·40		·147
T—U	·17		·00		·147
O—P	·22		·53		·221
R—S	·22		·00		·221
J—K		·75		1·06	·143
J—W		·75		·29	·143
J—M		·64		·81	·143
J—U		·64		·29	·143
J—O		·54		·55	·143
J—S		·54		·29	·143
J—Q		·42		·28	·143
L—M		·14		·34	·189
U—V		·14		·00	189
N—O		·18		·44	·244
S—T		·18		·00	·244
P—Q		·27		·58	·307
Q—R		·27		·30	·307

Explanations of Tables of Coefficients.

The tables of coefficients for the various types are calculated on the following assumptions :—

(1) Both shoes fixed.

(2) Effective span taken between the points of intersection of the rafters and main ties.

(3) Load uniformly distributed over both rafters and acting in a vertical direction.

(4) Wind pressure uniformly distributed over one rafter and acting at right angles to its surface.

(5) Purlins placed over the joints of intersection of the various members with the rafter.

To find the total stress in any number due to dead load and wind pressure combined :—

$$P=(W_D \times \text{dead load coefficient} + (W_p \times \text{wind pressure coefficient}).$$

Where P=total combined stress.

W_D=Total dead load on one truss comprising the weights of the truss, purlins and roof coverings.

W_p =Total normal wind pressure acting on one side of one truss.

L=Span between the points of intersection of the rafters and main ties.

To find the length of any number :—Multiply the span L by the length coefficient for the number required.

To calculate W_D *in lbs. :—*

L= Span of truss in feet.
C=Distance apart centre to centre in feet.
T=approx. weight in lbs. of one truss.
q=weight in lbs. of purlins and roof coverings per sq. foot.
Q=Total weight in lbs. of purlins and roof coverings supported by one truss.

$$T=\tfrac{3}{4}\ C\ L\ (1+\frac{L}{10})$$

$Q=q\times C\times 1{\cdot}12\ L$ for $\frac{1}{4}$ rise.

$Q=q\times C\times 1{\cdot}2\ L$ for $\frac{1}{3}$ rise.

Total dead load $W_D=T+Q$.

$W_p=P_n\times C\times{\cdot}56L$ for $\frac{1}{4}$ rise.

$=P_n\times C\times{\cdot}6\ L$ for $\frac{1}{3}$ rise.

Where P_n = normal wind pressure in lbs. per s ft. of roof surface.

$$P_n = P(\sin. i)^{1{\cdot}84 \cos. i - 1}.$$

Where P = Pressure in lbs. per s. ft.
i = angle of slope.

To find the pressure of wind :—

$P = {\cdot}0032\ V^2$ to ${\cdot}005\ V^2$.

Where P = pressure in lbs. per s. ft.
V = velocity in miles per hour.

For trusses of spans upto 60 feet the rafters are usually calculated and designed for the max. stress in the portion next to the shoe, the required section being continued to the apex. in one length. Special calculation should be made if the span is greater than 60 feet.

Truss Bearings.—Trusses must be securely anchored to the masonry with two anchor bolts at each bearing.

Truss span ..	..upto 30′	30—60′	70′	80′
Length of bolt ..	..2′-6″	3′-0″	3′-6″	4′-0″
Diameter of bolt ..	.. ⅝″	¾″	⅞″	1″

Economic Spacing of Trusses :—

Let D = economic spacing.

$$K = \frac{\text{Cost of Truss per cwt.}}{\text{Cost of purlins per cwt.}}$$

(1) For trusses carrying 25 to 60 lbs. per s. ft.

Where $K = 1\frac{1}{2}$ $\quad D = 3{\cdot}4\sqrt[3]{L}$

$K = 2$ $\quad D = 4\sqrt[3]{L}$

(2) For trusses carrying Jack arch ceilings.

Where $K = 1\frac{1}{2}$ $\quad D = 3\sqrt[3]{L}$

$K = 2$ $\quad D = 3{\cdot}6\sqrt[3]{L}$

Jack arch floors or roofs with one system of beams.

$D = \frac{L}{2}$ where only one beam is required.

$D = \frac{L}{3}$ where more than one beam is required.

Max. value of D = 6 feet.

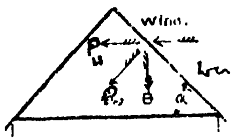
Trusses should never be less than 9 or 10 feet apart.

Roof Panels.—Number of panels $= \frac{\text{Span}}{5}$ approx.

Stresses in Trusses.—The stresses can be solved graphically or by means of coefficients for dead loads and wind pressure, given on pages (292-297). The latter method is simpler and quicker.

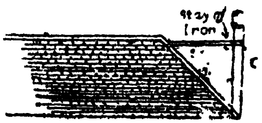
Name, Velocity and Force of Wind.

Name.	Velocity. Per hour.	Per second	Force per sq. foot, $\cdot 005V^2$.
	Miles.	Feet.	Lbs
Hardly perceptible wind	1	1·47	·005
Just perceptible	2	2·93	·020
	3	4·40	·044
Light pleasant breeze	4	5·87	·079
	5	7·33	·123
Pleasant brisk gale	10	14·67	·492
	15	22·00	1·107
Very Brisk	20	29·34	1·968
	25	36·67	3·075
High Winds	30	44·01	4·429
	35	51·34	6·027
Very High	40	58·68	7·873
	45	66·01	9·963
A storm or tempest	50	73·35	12·300
A great storm	60	88·02	17·715
A hurricane	80	117·36	31·490
Voilent Hurricane	100	147·30	50·001



α =angle of slope.
P_h=pressure of wind in lbs. per s. ft.
B =vertical pressure.
P_n=normal pressure.

$\alpha=$	5°	10°	20°	30°	40°	50°	60°	70°	80°
$P_n=P_h\times$	·173	·337	·612	·800	·910	·965	·989	·998	1·0
$B=P_h\times$	·172	·332	·576	·693	·697	·621	·495	·341	·173



The house stacks should be calculated for wind pressure and if found necessary a iron tie be given as shown in the diagram.

(1) Wind pressure on chimneys.

Allow 56 lbs. per sq. ft. of area.

If the wind pressure on a sq. chimney be considred=1.

Then Hexagon	=·75
Round	=·5
Octagonal	=·65

(2) Wind pressure on railway carriages—

A=area of carriage exposed to wind in sq. ft.

H=height of centre of pressure above rails in inches.

D=half distance apart of centres of rails in inches.

W=weight of a carriage in lbs.

P=Maximum wind pressure in lbs. per s. ft. beyond which vehicle is unstable $=\frac{WD}{AH}$

(3) Wind pressure on wires—

W=weight of wire in lbs. per mile.

L=length of wire in feet.

d=diameter of wire in inches.

f=pressure of wind in lbs. per s. ft.

F=total pressure of wind in lbs.

$F=\cdot0004723\ f\ L\ \sqrt{W}=\cdot0556\ f\ L.d$

EXAMPLE :—Span L = 30 feet.
Spacing C = 10 feet.
Rise = ¼th span.
Type 3*a*.

Covering 18 gauge G. corrugated sheeting on steel purlins, wind pressure horizontal=40 lbs. per s. ft.

$W_D = \frac{3\times10\times30}{4}\left(1+\frac{30}{10}\right)=900$ lbs. approx.

Purlins cleats and bolts	=2 lbs. per s. ft.
Sheetings and fittings	=3 lbs. per s. ft.
	q=5 lbs. per s. ft.

$Q=5\times10\times1\cdot12\times30=1680$ lbs.

$\therefore W_D = T + Q=900+1680=2580$ lbs. approx.

$P_n = P_h \times\cdot72=40\times\cdot725=29\cdot0$ lbs. per s. ft.

$W_P = 29\times10\times\cdot56\times30=4872$ lbs., say 5,000.

Stresses in Members.

Member.	Dead Load. Dead Load Stress Coefficient.	Dead Load. Stress in Tons = Coeff. × 2580/2240 Compression.	Dead Load. Stress in Tons = Coeff. × 2580/2240 Tension.	Wind Pressure. Wind Pressure Stress Coefficient.	Wind Pressure. Stress in Tons = Coeff. × 5000/2240 Compression.	Wind Pressure. Stress in Tons = Coeff. × 5000/2240 Tension.	Total Stress in Tons. Compression.	Total Stress in Tons. Tension.	Length. Length, Coefficient.	Length. Length in Feet = Coeff. × L.
A—H	1·080	1·24		1·251	2·80		4·04		·186	5·6
H—J	·165	·19		·368	·82		1·01		·107	3·2
K—L	·248	·28		·551	·123		1·51		·213	6·4
G—H	·968		1·12	1·356		3·03		4·15		
J—K	·132		·15	·296		·66		·81		
L—M	·412		·47	·437		·97		1·44		

The minimum size of angle or tee used in roof trusses should be 2″×2″×¼″ and the minimum size of flat, 2″×⅜″. In designing ties allow for loss of area due to holing. Use offset rods ⅝″ diam. and Sag ties ⅝″ diam.

Table of Steel Trusses of 16, 20, 24, 30, 40, and 50 *feet clear span Roof slope* 1 *in* 2 *camber* = *span* ÷ 28.

Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gussets* $\frac{3}{8}''$ *and* $\frac{1}{4}''$.

Span.	Roofing.	Member.	Truss 10′-0″ Centres. Stress.	Section.	Rivet.	Total	Truss 12′-6″. Stress.	Section.	Rivets.	Total
Span 16 ft. 4 Panels.	Single Tiles or Corrugated Sheets.	P.	Tons. 3·18	$2L^s\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2		Tons. 3·98	$2\ L^s\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2	
		C.S.	·83	1L do.	2		1·04	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2	
		H.T.	3·07	1L do.	2	4	4·20	$1L\ 2\frac{1}{2}\times2\times\frac{1}{4}$	3	5
		U.T.	1·51	1L do.	2		1·90	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2	
		C.T.	1·57	1L do.	2		1·98	1L do.	2	
		Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gussets* $\frac{3}{8}''$ *and* $\frac{1}{4}''$.								
Span 20 ft. 4 Panels.	Single Tiles or Corrugated Sheets.	P.	3·96	$2L^s\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2		4·95	$2L^s\ 2\times1\frac{1}{2}\times\frac{1}{4}$	3	
		C.S.	1·02	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2		1·28	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2	
		H.T.	3·73	$1L\ 2\times\ 2\times\frac{1}{4}$	3	13	4·66	$1L\ 2\frac{1}{2}\times2\times\frac{1}{4}$	3	14
		U.T.	1·87	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2		2·34	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2	
		C.T.	2·06	$1L\ 2\times1\frac{1}{2}\times\frac{1}{4}$	2		2·58	$2L^s\ 2\frac{1}{2}\times2\times\frac{1}{4}$	2	
		Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gussets* $\frac{3}{8}''$ *and* $\frac{1}{4}''$.								
Span 24 ft. 6 Panels.	Single Tiles or Corrugated Sheets.	P.	5·2	$2Ls\ 2\times1\frac{1}{2}\times\frac{1}{4}$	3		6·5	$2Ls\ 2\times1\frac{1}{2}\times\frac{1}{4}$	3	
		C.S.	1·2	$1L\ 2\times2\times\frac{1}{4}$	2		1·5	$1L\ 2\times2\times\frac{1}{4}$	2	
		H.T.	5·1	$2Ls\ 2\times1\frac{1}{2}\times\frac{1}{4}$	3	22	6·4	$2L^s\ 2\times1\frac{1}{2}\times\frac{1}{4}$	3	23
		U.T.	2·76	1L do.	2		3·45	1L do.	3	
		C.T.	2·48	1L do.	2		3·1	1L do.	2	
		Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gusset plate* $\frac{3}{8}''$ *and* $\frac{1}{4}''$.								

Table of Steel Trusses of 16, 20, 24, 30, 40 and 50 *feet clear span Roof slope* 1 *in* 2 *camber = span* ÷ 28.
Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gussets* $\frac{3}{8}''$ *and* $\frac{1}{4}''$.—*concld.*

Span.	Roofing.	Member.	Truss 10′.-0″ Centres Stress.	Section.	Rivet.	Total	Truss 12′.-6″. Stress.	Section.	Rivets	Total
Span 30 ft. 6 Panels.	Single Tiles or Corrugated Sheets.	P.	6·5	2Ls $2\frac{1}{2}\times 2\times\frac{1}{4}$	3		8·2	2Ls $2\frac{1}{2}\times 2\times\frac{1}{4}$	4	
		C.S.	1·48	1L do.	2		1·85	1L do.	2	
		H.T.	6·4	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	3	31	8·1	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	4	
		U.T.	3.5	1L do.	3		4·35	1L $2\frac{1}{2}\times 2\times\frac{1}{4}$	3	32
		C.T.	3·05	1L do.	2		3·8	1L do.	3	
			Diameter of Rivets $\frac{5}{8}''$; *Thickness of Gusset* $\frac{3}{8}''$ *and* $\frac{1}{8}''$.							
Span 40 ft. 8 Panels.	Single Tiles or Corrugated Sheets.	P.	9·25	2Ls $3\times 2\times\frac{1}{4}$	4		11·4	2Ls $3\times 2\times\frac{1}{4}$	5	
		C.S.	1·98	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	2		2·47	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	2	
		S.S.	1·01	1Ls do.	2		1·26	1L do.	2	41
		H.T.	9.0	2Ls do.	4	40	11·3	2Ls $2\times 2\times\frac{1}{4}$	5	
		U.T.	5·1	1L $3\times 2\times\frac{1}{4}$	4		6·9	1L $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	5	
		C.T.	4·2	1L $2\frac{1}{2}\times 2\times\frac{1}{4}$	3		5·2	1L $3\times 2\times\frac{1}{4}$	4	
		S.T.	1·98	1L $2\times 1\frac{1}{2}\times\frac{1}{4}$	2		1·85	1L $2\times 1\frac{1}{2}\times\frac{1}{4}$	2	
Span 50 ft. 10 Panels.	Single Tiles or Corrugated Sheets.	P	11·7	2Ls $3\times 2\frac{1}{2}\times\frac{1}{4}$	4		14·6	2Ls $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	5	
		C.S.	1·75	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	2		2 2	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	2	
		S.S.	1·00	1L do.	2		1·25	1Ls do.	2	
		H.T.	11·40	2Ls $2\frac{1}{2}\times 2\times\frac{1}{4}$	4	46	14·3	2Ls $3\times 2\times\frac{1}{4}$	5	47
		U.T.	6·65	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	3		8·3	2Ls $2\times 1\frac{1}{2}\times\frac{1}{4}$	3	
		C.T.	5·10	2Ls do.	2		6·35	2Ls do.	3	
		S.T.	1·40	1L do.	2		1·76	1L do.	2	

Table of Steel Trusses with Jack Arch Ceilings
Roof slope 1 in 2 Camber=Span ÷ 40.
Single tiles or Corrugated Sheeting 30lbs. per s. ft. Jack Arch Ceiling = 7 lbs per sq. foot.
All rivets ⅝″ diam. and gussets ⅜″ and ½″.

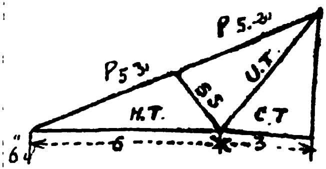
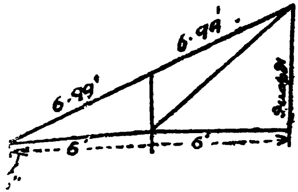
Span.	Member.	Truss 10′ Centres. Stress Tons.	Section.	Rivets.	Truss 12′-6″ Centres. Stress Tons.	Section.	Rivets.	
Span 16 to 18 ft. Clear	P	7·6	2Ls 2½×2×¼	4	9·5	2Ls 3×2×¼	4	
	S.S.	·77	1L 2×1½×¼	2	·89	1L 2×1½×¼	2	
	H.T.	6·85	2Ls do.	3	8·6	2Ls do.	4	
	U.T.	3·6	1L do.	2	4·5	1L 2½×2×¼	2	
	C.T.	4·35	2Ls do.	2	5·45	2Ls 2×1½×¼	3	
Span 24 ft. Clear.	P	10·6	2Ls 3×2½×¼	4	13·3	2Ls 3½×2½×¼	5	
	SS	·94	1L 2×1½×¼	2	1·17	1L 2×1½×¼	2	
	HT	9·6	2Ls 2×2×¼	3	12·0	2Ls 2½×2×¼	4	
	UT	4·2	1L 2½×2×¼	3	5·2	1L 3×2×¼	4	
	CT	6·6	2Ls 2×2×¼	3	8·2	2Ls 2½×2×¼	3	
	Suspdr	2·5	1L 2×1½×¼	2	3·1	1L 2×1½×¼	2	

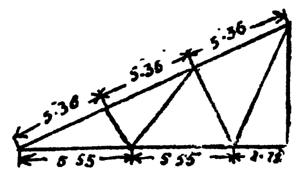
Table of Steel Trusses with Jack Arch Ceilings—*concld.*

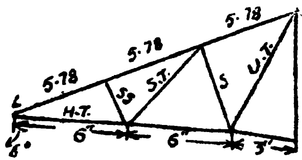
Roof slope 1 in 2 Camber=Span ÷ 40.

Single tiles or Corrugated Sheeting 30 lbs. per s. ft. Jack Arch Ceiling = 7 lbs. per sq. foot.

All rivets $\frac{5}{8}''$ diam. and gussets $\frac{3}{8}°$ and $\frac{1}{4}°$.

		Truss 10′ Centres.			Truss 12′-6″ Centres.		
	Member.	Stress Tons.	Section,	Rivets.	Stress Tons.	Section.	Rivets.
Span 27′-9″ Clear.	P	14·1	2L $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	5	17·6	2L $5\times2\times\frac{3}{8}$	6
	S	1·92	1L $2\frac{1}{2}\times2\times\frac{1}{4}$	2	2·4	1L $3\times2\times\frac{1}{4}$	2
	SS	·69	1L $2\times1\frac{1}{2}\times\frac{1}{4}$	2	·86	1L $3\times1\frac{1}{2}\times\frac{1}{4}$	2
	HT	12·6	2L $2\frac{1}{2}\times2\times\frac{1}{4}$	4	15·8	2Ls $3\times2\frac{1}{2}\times\frac{1}{4}$	5
	UT	4·8	1L do.	3	6·0	1L do.	4
	CT	7·3	2Ls $2\times1\frac{1}{2}\times\frac{1}{4}$	3	9·2	2Ls $2\times1\frac{1}{2}\times\frac{1}{4}$	3
	ST	3·2	1L do.	2	4·0	1L $2\times2\times\frac{1}{4}$	3
Span 30 ft. Clear.	P	15·2	2Ls $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	5	19·0	2L $3\frac{1}{2}\times2\frac{1}{2}\times\frac{5}{16}$	6
	S	2·08	1L $3\times2\times\frac{1}{4}$	2	2·6	1L $3\times2\frac{1}{2}\times\frac{1}{4}$	2
	SS	·74	1L $2\times\frac{1}{2}\times\frac{1}{4}$	2	·93	1L $2\times1\frac{1}{2}\times\frac{1}{4}$	2
	UT	5·6	1L $3\times2\times\frac{1}{4}$	4	6·5	1L $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	4
	CT	7·9	2Ls $2\times1\frac{1}{2}\times\frac{1}{4}$	3	9·9	2Ls $2\times2\times\frac{1}{4}$	3
	ST	3·5	1L do.	2	4·35	1L $2\frac{1}{2}\times2\times\frac{1}{4}$	3
	HT	13·6	2Ls $3\times2\times\frac{1}{4}$	5	17·0	2Ls $3\times2\frac{1}{2}\times\frac{1}{4}$	6





Jack Arch Roofs.

Table of dimensions of tie-rods required for arched roofs of several spans.

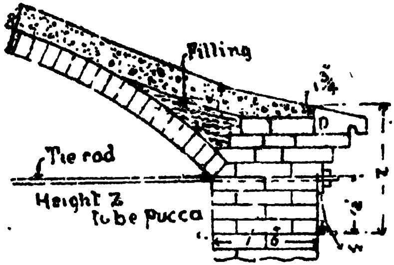
S=Span.	Thickness of arching.	Rise of Arch.		Diameter of tie rod.		Dimensions of washers and backing plates.
		$\frac{S}{6}$	$\frac{S}{4}$	Rise $=\frac{S}{6}$	Rise $=\frac{S}{4}$	
Ft.	Ins.	Ft. Ins.	Ft. Ins.	Ins.	Ins.	
3	$4\frac{1}{2}$	0—6	..	$\frac{1}{2}$	..	Washers $9'' \times 4\frac{1}{2} \times \frac{3}{4}''$.
4	$4\frac{1}{2}$	0—8	..	$\frac{1}{2}$	..	
6	,,	1—0	..	$\frac{3}{8}$	..	
8	,,	1—4	..	$\frac{3}{4}$	..	
10	9	1—8	..	$\frac{7}{8}$	..	Continuous thrust Plates of angle iron $3'' \times 3'' \times \frac{3}{8}''$
12	,,	2—0	3—0	$\frac{7}{8}$	$\frac{3}{4}$	
14	,,	2—4	3—6	1	$\frac{7}{8}$	
16	,,	2—8	4—0	1	1	Continuous thrust plates of angle iron $4'' \times 4'' \times \frac{3}{8}$
18	,,	3—0	4—6	$1\frac{1}{8}$	1	
20	,,	3—4	5—0	$1\frac{1}{8}$	$1\frac{1}{8}$	

Tie rods have been used 4 feet from centre to centre and concrete 3 inches thick over the arch.

The following should be always kept in view :—

(*a*) For spans up to 10 feet the spacings of tie-rods should never exceed 5 feet. Diamond shaped washers (like one given in the sketch) of cast iron or wrought iron should be used at the end of tie-rods (see W in figure on the following page).

Thickness of arch should not be less than $4\frac{1}{2}$ inches as 



(*b*) The spacings of tie-rods should not exceed 4′ for spans 10 to 20 feet.

The washers should be of angle iron.

See Table above.

(*c*) The concrete should be placed on the roofs as shown in the sketch. The concrete should not extend to the outer face of the walls. No parapets is to be used in such construction.

(*d*) The thickness of concrete near D should be at least $1\frac{3}{4}''$. Do the filling as soon as the centerings are lowered and place the concrete after 20 to 25 days.

(*e*) The top courses, *i. e.*, above *a b* should be in line. Springing line should be at least 12 feet from the floor level.

Method of finding thickness of tie-rod.

EXAMPLE.—Find the thickness of tie-rod, placed 5 feet centre to centre used on 60° arch, 1 feet thick, the width of the room being 20′. The weight of masonry=120 lbs. per c.ft.

Area of arch $= \dfrac{\pi \times 2 \times 20\frac{1}{2}}{6} = 21{\cdot}4676$ square feet.

Area for $\frac{1}{2}$ span=10·7338 square feet.

Weight on one tie-rod=120×5×10·7338=6440 lbs.

If H=Stress set up in tie-rod.

Then H=6440 × Cot 30=11154 lbs.

Safe Tensile stress of iron= 8960 lbs. per square foot.

Safe Tensile stress of steel=11200 lbs. per square foot.

∴Sectional area of iron bar $= \dfrac{11154}{8960} = 1{\cdot}24$ square ft.

and sectional area of steel bar $= \dfrac{11154}{11200} = {\cdot}995$ square ft.

∴Diameter of iron bar $=1\frac{1}{16}$ inch.

and diameter of steel bar $=1\frac{1}{8}$ inch.

NOTE.—In the above table the thickness of the arch is 9″.

EXAMPLE 2.—Find the spacings of tie-rods, 1 inch thick used on 60° arch of 1 foot thickness when

(*i*) The width of the room be 24 feet.

(*ii*) Safe tensile stress of iron be 5 tons per s. ft. and weight of arch masonry be 120 lbs. per c. ft. (See figure for example No. 1).

Sectional area of arch masonry	$= \frac{\times 2 \times 24{\cdot}5}{6}$ ·25·7 s. ft.
Masonry for 1′ length of arch	$= 25{\cdot}7 \times 1 = 25{\cdot}7$ c. ft.
Weight of arch for 1′ length	$= 25{\cdot}7 \times 120 = 3084$ lbs.
Weight on one rod	$= \frac{3084}{2} = 1542$ lbs.
∴ Stress set up in tie rod	$= 1542 \times \text{Cot } 30° \cdot 0''$
	$= 1542 \times 1{\cdot}73205 \quad = 2671$ lbs.
Sectional area of tie rod	$= \pi \times (\frac{1}{2})^2 = {\cdot}7854$ s. inch.
∴ Safe Tensile stress	$= {\cdot}7854 \times 5$ tons.
	$= {\cdot}7854 \times 11200 \quad = 8796$ lbs.
∴ Spacings	$= \frac{8796}{2671}$
	= 3 feet 3 inch.

Safe Loads on Deodar and Kail Planking.

Span in ft.	Safe Superimposed Loads in lbs. per sq. foot.				
	1″	1½″	2″	2½″	3″
1·5	356				
2·0	150	506			
2·5	77	259	614		
3·0	44	150	356	694	
3·5		94	224	437	756
4·0		63	150	293	506
4·5		44	105	192	356
5·0			77	150	259
5·5			58	112	195
6·0			44	87	150

Table showing Diameter of Deodar or Sal Ballies for 80 *lbs. roof.*

Span in ft.	Deodar Ballies Spacing C to C		Sal Ballies Spacing C to C.	
	1 ft. Inches.	1½ ft. Inches.	1 ft. Inches.	1½ ft. Inches.
4	3	3½	2¾	3
5	3½	4	3¼	3½
6	4	4½	3¾	4
7	4½	5	4¼	4¾
8	4¾	5½	4½	5
9	5¼	6	5	5½
10	5½	6½	5¼	5¾
11	6¼	6¾	6	6½
12	6½	7¼	6¼	7

New British Rolled Steel Joists.

Size in Inches.	Weight per Foot in Lbs.	Diagrams. Web. t	Diagrams. Flange T.	Diagrams. Radius R1	Diagrams. Radius R2	Area in square Inches.	Moments of Inertia About x—x	Moments of Inertia About y—y	Radii of Gyration in Inches. About x—x	Radii of Gyration in Inches. About y—y	Section Modulus about X—X
Girder Sections.											
24×7½	90	·52	·984	·73	·36	26·47	2443	60 44	9·61	1·51	203 6
22×7	75	·50	·834	·69	·34	22·06	1677	41·07	8·72	1·36	152·4
20×6½	65	·45	·820	·65	·32	19·12	1226	32·56	8·01	1·31	122·6
18×6	55	·42	·757	·61	·30	16·18	841·8	23·64	7·21	1·21	93·53
16×6	50	·40	·726	·61	·30	14·71	618·1	22·47	6·48	1·24	77·26
15×6	45	·38	655	·61	·30	13·24	491·9	19 87	6·10	1·23	65·59
14×5½	40	·37	·627	·57	·28	11·77	377·1	14·79	5·66	1·12	53·87
13×5	35	·35	·604	·53	·26	10·30	283·5	10·82	5·25	1·03	43·62
12×5	30	·33	·507	·53	·26	8·827	206·9	8·770	4·84	·997	34·49
10×4½	25	·30	·505	·49	·24	7·354	122·3	6·486	4·08	·939	24·47
9×4	21	·30	·457	·45	·22	6·177	81·13	4·148	3·62	·820	18·03
8×4	18	·28	·398	·45	·22	5·296	55·63	3·506	3 24	·814	13·91
7×3½	15	25	·398	·41	·20	4·416	35 90	2·408	2·85	·738	10·26
6×3	12	·23	·377	·37	·18	3·533	20·99	1·461	2·44	·643	6·996
5×2½	9	·20	·347	·33	·16	2·647	10·91	·789	2·03	·546	4·364
4½×2	7	·19	·322	·29	·14	2·060	6·652	·383	1·80	·431	2·957
4×1¾	5	·17	·239	·27	·13	1·470	3·664	·186	1·58	·356	1·832
3×1½	4	·16	·249	·25	·12	1·177	1·660	·125	1·19	·326	1·107
Heavy Beams.											
18×8	80	·50	·950	·77	·38	23·53	1292	69·43	7·41	1·72	143·6
16×8	75	·48	·938	·77	·38	22·06	973·9	6[illegible]·30	6·64	1·76	121·7
14×8	70	·46	·920	·77	·38	20·59	705·6	66·67	5·85	1·80	100·8
12×8	65	·43	·904	·77	·38	19·12	487·8	65·18	5·05	1·85	81·30
10×8	55	·40	·783	·77	·38	16·18	288·7	54·74	4·22	1·84	57·74
10×6	40	·36	·709	·61	·30	11·77	204·8	21·76	4·17	1·36	40·96
9×7	50	·40	·825	·69	·34	14·71	208·1	40·17	3·76	1·65	46·25
8×6	35	·35	·648	·61	·30	10·30	115·1	19·54	3·34	1·38	28·76
6×5	25	·33	·561	·53	·26	7·351	45·16	9·876	2·48	1·16	15·05
5×4½	20	·29	·513	·49	·24	5·882	25·03	6·590	2·06	1·06	10·01
4×3	10	·24	·347	·37	·18	2·940	7·786	1·326	1·63	·672	3·893

(2) BRIDGES AND CULVERTS.

Foundations must always be taken down deep enough to be free from the scouring action of flood water.

Culverts should, when possible, be designed in one span. The span for bridges should be chosen as large as possible and should be few in number.

The cost per span is minimum when the cost of the span carrying load direct to piers is equal to the cost of one pier.

Let L =Span in feet.
H=Total height of pier.

The economic span is as follows:—

(1) Steel trusses span on masonry piers L=3H
(2) Masonry arches L=2H or more.
(3) Reinforced concrete slab on masonry piers L=$1\frac{1}{2}$H.
(4) Steel troughing R. S. joists and reinforced concrete beams on masonry piers L=$\frac{3}{4}$ H to H.

For the economy in material, the rise of the arch should be between $\frac{1}{2}$ to $\frac{1}{4}$ of the spans and the spans should be not less than the height (in the case of culverts) or not less than $1\frac{1}{2}$ times to twice the height in the case of bridges.

It is more economical to increase the span than to increase the height for the same area of openings.

The following calculations should be made before designing a bridge:—

1. Find the (mean) velocity of the stream.
2. Find the afflux due to obstruction such as piers.
3. Find the velocity under the arches.
4. Find the depth to which the bed will scour.

I. To find the velocity of stream use Manning's formula:—

$$V=\frac{1\cdot486}{n}r^{\frac{2}{3}}S^{\frac{1}{2}}$$

Where V=mean velocity in feet per second.

$$r=\text{hydraulic mean depth}=\frac{\text{Area}}{\text{wetted perimeter.}}$$

S=inclination of water surface

Value of n is the same as in Kutter's formula.

Brickwork and cut stone	n=·013
Rubble masonry	n=·017
Very fine gravel	n=·020
Rivers and canals in earth	n=·025
Rivers and canals in bad order	n=·030
Torrential streams with beds covered with Detritus	n=·050

II. To find the afflux due to obstruction

use— $$h=\left\{\frac{V^2}{58\cdot6}+0\cdot05\right\}\left\{\left(\frac{A}{a}\right)^2-1\right\}$$

Where h=afflux of water caused by the obstruction in feet.

V=mean velocity of river in feet per second at max. H. F. L.

A=area of river unobstructed in square feet.

a=area of river at obstruction in square feet neglecting the afflux.

Mean velocity of current in feet per second before obstruction.	$\frac{A}{a}=1{\cdot}11$ or $\frac{a}{A}=\cdot9$	1·25 / ·8	1·43 / ·7	1·67 / ·6	2·0 / ·5
	Afflux or rise of water level in feet.				
2	·03	·07	·12	·21	·35
4	·07	·18	·34	·57	·97
6	·15	·37	·69	1·18	2·00
8	·26	·64	1·19	2·03	3·42
10	·40	·98	1·83	3·12	5·25
12	·58	1·41	2·62	4·45	7·50
15	·90	2·19	4·06	6·92	11·70
20	1·59	3·87	7·18	12·2	..
25	2·48	6·00	11·15	..	..
30	3·57	8·65	..	..	..

(*III*). *To find the Velocity under the Arches or Girders.*

$$V_1 = \frac{1{\cdot}1\,AV}{a}$$

Where a, A, V are the same as before—

V_1 =velocity under arches.

1·1 is the factor to allow for eddies.

IV. *To find the depth to which the bed will scour*—

$$V_2 = {\cdot}84\,k d_1^{0{\cdot}64}$$

d_1 =average depth before scour.

V_2 =velocity after scour.

K =1 for coarse sand.

=1·5 for coarse gravel.

=2 to 3 for large boulders.

The effect of different velocities of water in scouring various soils close to the bed is given below.

¼ ft. per second will scour fine clay, river mud or silt

½ " " " " " sand and common clay.

¾ " " " " " coarse sand.

1 " " " " " fine gravel.

2	feet	per second	will	scour		Round shingle 1" diameter.
3	„	„	„	„	„	Large stone as big as egg.
5	„	„	„	„	„	Conglomerate.
6	„	„	„	„	„	rocks with distinct layers.
10	„	„	„	„	„	hard rock.

Chailly's formula for velocity that will move stones.

$$D = \frac{V^2}{85}$$ where D=diameter of stone in feet

V=velocity of water in feet per second.

For V =	5	10	15	20	25	30	35	40
D =	·3	1·2	4·7	7·3	10·6	14·4	16·6	18·8 feet

The depth of the moving bed caused by scour occasioned by the highest known flood can be found by trial holes and can be calculated by Kennyd's formula.

$$V = \cdot 84\ Kd^{\cdot 64}$$

K varying up to 3 according to the nature of bed.

Design of Culverts and Small Bridges.

For culverts and small bridges measure the drainage area and make the openings large enough to carry off 3" to 4" of rainfall in one hour or deduce from the following formula :—

If a=area of opening in square feet

A=drainage area in acres

C=coefficient $\begin{cases} \text{flat country} & C=1 \\ \text{rocky ground} & C=1{\cdot}5 \\ \text{Mountaineous} & C=4 \end{cases}$

Meyer= $a = C\sqrt{A}$

Chamier $Q = 640\ C.\ R.\ M^{\frac{3}{4}}$

Where Q=Max. discharge at the outlet in cubic feet per second.

R=average max. rainfall in inches per hour.

C=coefficient of surface discharge.

M=catchment area in square miles.

Value of C for flat country, sandy soil or cultivated land	=·25 to ·35
Wooded hill slopes stony ground	=·45 to ·55
Mountaineous country non-absorbent	=·53 to ·65
Bare mountains and paved surface	=·8 and over.

Dickens :—

D=Max flood discharge in c. ft. per second.
M=Catchment area in square miles.

$D=825\ M^{\frac{3}{4}}=CM^{\frac{3}{4}}$

e's :—

$D=CM^{\frac{2}{3}}$. (Used in Madras).

Table showing sizes of bridges based upon drainage area and assumed velocities.

Drainage area.	Discharge, cubic feet per second.	Assumed velocity feet per second.	Square feet of waterway.	BRIDGE FOR COMMON CASES.		
				Number of spans	Span in feet.	Height of piers or abutment.
1 acre	6½	5	1½	1	1½	1
2 ,,	11	5	2¼	1	2	1½
3 ,,	15	5	3	1	2	1½
5 ,,	22	5	..	1	3	1½
8 ,,	31	5	6	1	3	2
16 ,,	52	5	10½	1	4	2½
40 ,,	103	6	18	..	6	3
¼ square mile	173	6	29	1	7	4
½ ,,	292	6	49	1	10	5
¾ ,,	490	6	81	1	12	6
1 ,,	825	6	137	2	12	6
2 ,,	1388	7	200	3	12	6
3 ,,	1881	7	270	3	14	7
5 ,,	2760	7	400	3	16	8
7 ,,	3550	7	500	3	18	9
10 ,,	4640	7	663	3	20	10
20 ,,	7804	8	975	5	20	11
30 ,,	10577	8	1322	5	24	11
50 ,,	15605	9	1734	5	30	11½
100 ,,	26094	9	2899	5	40	14½

Abutments :—

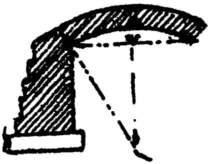
Abutment walls should be designed to resist the earth and not the arch thrust.



The thickness of abutment should not be less than span .

Method of finding Thickness of Abutment :—

With centre C and radius equal to CA, *i. e.*, of arch, draw arc to cut at B. Now this arch should remain inside the abutment.



Piers—$\frac{1}{6}$ to $\frac{1}{5}$ span.

Backing $\frac{1}{3}$ rise of arch from springing line.

Dimensions of Railway Bridges.

See pages (328—330) and dia grams pages (701—748).

$$R = \frac{\text{span}}{2} + 12''.$$

If span = 24′

$$\text{Rise} = \frac{24}{2} + 1 = 13 \text{ feet.}$$

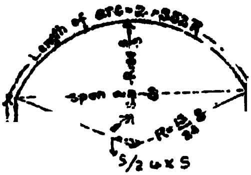
Thickness of Arch:—

Small type $t = \frac{s}{2} + 9''$

if span =24′, thickness$= \frac{24}{2} + 9 = 21''$

For heavy type of bridges $t = \frac{3}{4}s + 9''$

i. e., if span =24′ $t = \frac{3 \times 24}{4} + 9 = 27''$



and for very heavy type $t = s + 9'' = 33''$.

Height of Springing Line from G. L.$= \frac{S}{2}$

Rise of arch $= \frac{S}{3}$

Length of arch =2·352 R.

The thickness of arch and filling (earth) should $= \frac{S}{6} + 2$ feet.

Height of parapet from ground level to top of parapet=s′+2′.

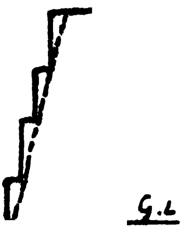
Thickness of intermediate pier:—

(1) for light type $= S \times 1\frac{1}{4} + 22\frac{1}{2}'' = 42\frac{1}{2}''$ (span 16′)

(2) for heavy type $= S \times 1\frac{25}{32} + 22\frac{1}{2}'' = 51''$ (span 16′)

(3) Very heavy type $= S \times 2\frac{1}{4} + 22\frac{1}{2}'' = 58\frac{1}{2}''$ (span 16′).

Thickness of abutment:—



(1) for light type$= \frac{S}{3} + 1' = 9'$ (span 24′).

(2) for heavy type $= \frac{S}{3} + 1 = 9'$ (span 24′).

(3) very heavy type$= \frac{3}{8}$ S $+1 = 10'$ (span 24′).

All these thicknesses are at G. L. The front face should be vertical and back face should have batter 1 in 4. When giving offsets the line of batter should be inside the offsets as shown in the sketch.

Thickness of Abutment for 60° Arches.

Height to springing.	Spans.																		Remarks.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	
1·5	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9	5·1	5·3	5·5	5·7	5·9	
2·0	2·7	2·9	3·1	3·4	3·6	3·8	4·0	4·3	4·5	4·7	4·9	5·0	5·3	5·4	5·6	5·9	6·0	6·2	
2·5	3·0	3·3	3·5	3·7	4·0	4·1	4·4	4·6	4·9	5·0	5·2	5·5	5·6	5·8	6·0	6·2	6·3	6·5	
3·0	3·3	3·5	3·7	4·0	4·3	4·5	4·7	5·0	5·3	5·4	5·6	5·8	6·0	6·1	6·4	6·5	6·7	6·9	
3·5		3·7	4·0	4·3	4·6	4·8	5·0	5·3	5·6	5·7	6·0	6·1	6·4	6·6	6·7	6·9	7·1	7·3	
4·0		4·0	4·3	4·6	4·9	5·1	5·3	5·6	5·8	6·0	6·3	6·4	6·7	6·9	7·0	7·2	7·4	7·6	
4·5			4·6	4·9	5·0	5·3	5·6	5·9	6·1	6·4	6·6	6·9	7·0	7·2	7·5	7·6	7·7	7·9	
5·0			4·8	5·0	5·3	5·5	5·8	6·1	6·5	6·6	7·0	7·2	7·4	7·5	7·8	8·0	8·2	8·4	
5·5			5·0	5·2	5·5	5·8	6·0	6·4	6·7	7·0	7·3	7·5	7·7	7·9	8·1	8·3	8·5	8·7	
6·0				5·4	5·7	6·0	6·3	6·6	7·0	7·3	7·5	7·7	8·0	8·2	8·5	8·6	8·8	9·0	
6·5					5·9	6·2	6·5	6·9	7·3	7·5	7·8	8·0	8·3	8·5	8·8	9·0	9·2	9·4	
7·0					6·0	6·4	6·7	7·1	7·4	7·8	8·0	8·3	8·6	8·8	9·0	9·3	9·5	9·6	
7·5						6·8	7·0	7·3	7·6	8·0	8·3	8·6	8·9	9·1	9·4	9·6	9·8	10·0	
8·0						6·9	7·2	7·5	7·8	8·1	8·5	8·8	9·1	9·3	9·6	9·8	10·0	10·3	
8·5							7·4	7·6	8·0	8·4	8·7	9·0	9·4	9·6	9·9	10·0	10·3	10·5	
9·0							7·5	7·8	8·1	8·5	8·9	9·2	9·5	9·7	10·0	10·3	10·5	10·7	
9·5								7·9	8·3	8·7	9·0	9·3	9·6	9·9	10·3	10·5	10·7	11·0	
10·0								8·0	8·4	8·9	9·2	9·4	9·7	10·0	10·4	10·6	10·9	11·2	

Thickness of Abutments for 75° Arches.

Height to springing.	Spans. 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Remarks.
1·0	1·8	2·1	2·4	2·5	2·6	2·7	2·9	3·1	3·3	3·4	3·5	3·7	3·8	4·0	4·2	4·3	4·5	4·6	
1·5	2·0	2·3	2·5	2·6	2·9	3·1	3·3	3·4	3·6	3·7	3·8	4·0	4·2	4·4	4·5	4·6	4·7	4·9	
2·0	2·3	2·4	2·7	2·9	3·2	3·3	3·5	3·6	3·8	4·0	4·2	4·3	4·4	4·6	4·8	4·9	5·1	5·3	
2·5	2·5	2·7	2·9	3·2	3·4	3·6	3·8	3·9	4·2	4·4	4·5	4·6	4·9	5·1	5·3	5·4	5·5	5·6	
3·0	2·6	2·8	3·1	3·3	3·5	3·8	4·0	4·2	4·5	4·6	4·8	4·9	5·1	5·3	5·4	5·5	5·6	5·7	
3·5		3·0	3·3	3·5	3·7	4·0	4·3	4·6	4·8	4·9	5·1	5·2	5·4	5·5	5·6	5·7	5·9	6·0	
4·0		3·2	3·4	3·7	4·0	4·3	4·6	4·8	5·0	5·2	5·4	5·5	5·6	5·7	5·9	6·1	6·3	6·4	
4·5			3·6	3·9	4·3	4·6	4·9	5·1	5·4	5·5	5·6	5·8	5·9	6·1	6·4	6·5	6·7	6·8	
5·0				4·1	4·5	4·8	5·1	5·3	5·5	5·7	6·0	6·2	6·4	6·5	6·6	6·7	6·9	7·0	
5·5				4·3	4·7	5·0	5·4	5·5	5·8	6·0	6·3	6·4	6·6	6·7	7·0	7·1	7·3	7·4	
6·0				4·6	4·9	5·2	5·5	5·8	6·0	6·3	6·5	6·6	6·8	7·0	7·3	7·4	7·5	7·6	
6·5					5·0	5·4	5·6	6·0	6·3	6·5	6·7	6·9	7·1	7·3	7·5	7·6	7·7	7·8	
7·0					5·2	5·5	5·8	6·1	6·4	6·7	6·9	7·2	7·3	7·4	7·6	7·7	8·0	8·2	
7·5						5·6	6·0	6·3	6·6	6·9	7·2	7·4	7·5	7·6	7·9	8·1	8·4	8·5	
8·0						5·9	6·2	6·4	6·8	7·2	7·4	7·5	7·7	7·9	8·2	8·4	8·5	8·6	
8·5							6·4	6·7	7·1	7·3	7·5	7·7	7·9	8·2	8·4	8·6	8·8	8·9	
9·0							6·5	6·8	7·2	7·4	7·6	7·8	8·1	8·3	8·5	8·7	9·1	9·3	
9·5								6·9	7·3	7·6	7·9	8·1	8·4	8·5	8·8	9·0	9·3	9·4	
10·0								7·0	7·4	7·7	8·0	8·3	8·5	8·6	8·9	9·3	9·4	9·6	

Thickness of Abutments for 90° Arches.

Height to springing.	Spans.																		Remarks.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1·0	1·5	1·7	2·0	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·1	3·2	3·3	3·4	3·5	3·6	3·7	
1·5	1·7	2·0	2·3	2·4	2·5	2·6	2·7	2·9	3·0	3·1	3·2	3·3	3·4	3·6	3·6	3·7	3·8	3·9	
2·0	2·0	2·2	2·4	2·6	2·7	2·9	3·0	3·2	3·3	3·4	3·5	3·6	3·7	3·9	3·9	4·0	4·1	4·2	
2·5	2·2	2·4	2·6	2·7	3·0	3·2	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·4	4·5	
3·0	2·4	2·6	2·7	3·1	3·3	3·4	3·6	3·7	3·9	3·9	4·0	4·2	4·3	4·4	4·5	4·6	4·7	4·8	
3·5		2·7	3·0	3·3	3·5	3·6	3·7	3·8	4·0	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·1	
4·0		2·9	3·2	3·4	3·8	3·8	3·8	4·1	4·3	4·4	4·5	4·6	4·7	4·9	5·0	5·1	5·2	5·3	
4·5			3·4	3·6	3·9	4·1	4·3	4·4	4·6	4·7	4·9	5·0	5·2	5·3	5·4	5·5	5·6	5·7	
5·0				3·7	4·0	4·3	4·5	4·7	4·9	5·1	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	
5·5				3·9	4·1	4·4	4·6	4·9	5·1	5·3	5·5	5·6	5·7	5·8	6·0	6·1	6·3	6·4	
6·0				4·0	4·3	4·6	4·8	5·0	5·3	5·4	5·6	5·7	5·9	6·1	6·3	6·4	6·5	6·6	
6·5					4·5	4·7	5·0	5·3	5·5	5·6	5·8	6·0	6·2	6·3	6·5	6·6	6·7	6·8	
7·0					4·6	4·9	5·2	5·4	5·6	5·8	6·1	6·2	6·4	6·5	6·6	6·9	7·0	7·1	
7·5						5·0	5·3	5·5	5·8	6·0	6·3	6·4	6·5	6·7	6·9	7·1	7·3	7·4	
8·0						5·1	5·4	5·6	6·0	6·2	6·4	6·5	6·7	6·9	7·1	7·3	7·4	7·5	
8·5							5·5	5·8	6·1	6·4	6·6	6·7	6·9	7·1	7·3	7·5	7·6	7·7	
9·0							5·6	5·9	6·2	6·5	6·7	6·9	7·1	7·3	7·5	7·6	7·7	7·9	
9·5								6·0	6·3	6·6	6·8	7·0	7·3	7·4	7·6	7·7	8·0	8·2	
10·0								6·1	6·4	6·7	6·9	7·2	7·4	7·5	7·7	7·9	8·2	8·4	

Thickness of Abutments for 120° Arches.

Height to springing.	Spans.																		Remarks.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1·0	1·0	1·2	1·5	1·6	1·8	2·0	2·1	2·2	2·3	2·34	2·4	2·45	2·5	2·6	2·7	2·8	2·9	3·0	
1·5	1·2	1·4	1·6	1·8	2·1	2·2	2·3	2·4	2·5	2·6	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	
2·0	1·4	1·6	2·0	2·1	2·2	2·3	2·4	2·6	2·7	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	
2·5	1·9	2·0	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	
3·0	2·0	2·1	2·3	2·4	2·6	2·7	2·9	3·0	3·1	3·2	3·3	3·4	3·45	3·5	3·55	3·6	3·7	3·8	
3·5		2·3	2·5	2·6	2·8	3·0	3·2	3·3	3·4	3·5	3·55	3·6	3·65	3·7	3·8	3·9	4·0	4·1	
4·0		2·5	2·6	2·7	3·0	3·2	3·3	3·4	3·5	3·6	3·65	3·7	3·9	3·9	4·0	4·1	4·2	4·3	
4·5			2·8	3·0	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·35	4·4	4·5	
5·0			3·0	3·2	3·4	3·5	3·6	3·7	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·55	4·6	4·7	
5·5				3·3	3·5	3·6	3·7	3·9	4·1	4·2	4·3	4·35	4·4	4·5	4·55	4·6	4·7	4·8	
6·0				3·4	3·6	3·7	3·8	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	
6·5					3·7	3·9	4·1	4·2	4·3	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	
7·0					3·9	4·1	4·3	4·4	4·5	4·6	4·7	4·8	5·0	5·1	5·2	5·3	5·4	5·5	
7·5						4·2	4·4	4·5	4·6	4·7	4·9	5·0	5·2	5·3	5·4	5·5	5·6	5·7	
8·0						4·3	4·5	4·6	4·7	4·9	5·1	5·2	5·3	5·4	5·6	5·7	5·8	5·9	
8·5							4·6	4·7	5·0	5·1	5·3	5·4	5·5	5·6	5·7	5·8	6·0	6·1	
9·0							4·8	4·9	5·1	5·2	5·4	5·5	5·6	5·7	5·9	6·1	6·2	6·3	
9·5								5·0	5·2	5·3	5·5	5·6	5·8	5·9	6·1	6·2	6·3	6·4	
10·0								5·1	5·3	5·4	5·6	5·7	5·9	6·1	6·2	6·3	6·5	6·6	

Thickness of Abutments for Semicircular Arches.

Height to springing.	Spans.																		Remarks.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1·0	1·8	1·9	2·0	2·2	2·3	2·4	2·5	2·6	2·7	2·8	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	
1·5	1·9	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2 9	3·1	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	
2·0	2·2	2·3	2·4	2·5	2·6	2·7	2·8	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·9	4·1	4·2	4·3	
2·5	2·3	2·4	2·5	2·6	2·7	2·9	3·1	3·3	3·4	3·5	3·6	3·7	3·8	4·0	4·2	4·3	4·4	4·5	
3·0		2·6	2·7	2·8	2·9	3·1	3·3	3·4	3·5	3·6	3·7	3·8	4·1	4·2	4·3	4·4	4·5	4·6	
3·5		2·8	2·9	3·1	3·2	3·4	3·5	3·6	3·7	3·9	4·0	4·1	4·2	4·3	4·5	4·6	4·7	4·8	
4·0				3·2	3·3	3·4	3·6	3·7	3·9	4·0	4·2	4·3	4·4	4·5	4·6	4·7	4·8	5·0	
4·5					3·4	3·5	3·8	3·9	4·0	4·2	4·3	4·4	4·5	4·6	4·8	4·9	5·1	5·2	
5·0						3·7	3·9	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·9	5·1	5·2	5·3	
5·5							4·0	4·2	4·3	4·4	4·5	4·6	4·8	5·0	5·2	5·3	5·4	5·5	
6·0								4·3	4·4	4·5	4·7	4·8	5·0	5·2	5·3	5·4	5·5	5·6	
6·5									4·5	4·6	4·8	5·0	5·2	5·3	5·4	5·5	5·6	5·8	
7·0										4·8	5·0	5·1	5·3	5·4	5·5	5·6	5·8	5·9	
7·5											5·1	5·2	5·4	5·5	5·6	5·8	5·9	6·1	
8·0												5·3	5·5	5·6	5·8	6·0	6·2	6·3	
8·5													5·6	5·7	6·0	6·1	6·3	6·4	
9·0														5·9	6·1	6·2	6·4	6·45	
9·5															6·3	6·4	6·45	6·5	
10·0																6·45	6·5	6·6	

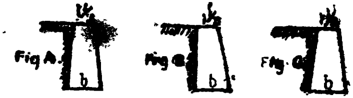


Table for Value of b. for Brick-work in Retaining Walls.

Height.	EARTH. Natural slope ½ to 1. Plumb faced, Fig. A.	Natural slope ½ to 1. Plumb backed, Fig. B.	Natural slope ½ to 1. Front batter 1 in 12, Fig. C.	Natural slope 1 to 1. Plumb faced, Fig. A.	Natural slope 1 to 1. Plumb backed, Fig. B.	Natural slope 1 to 1. Front batter 1 in 12, Fig. C.	Natural slope 2 to 1. Plumb faced, Fig. A.	Natural slope 2 to 1. Plumb backed, Fig. B.	Natural slope 2 to 1. Front batter 1 in 12, Fig C.	Natural slope 3 to 1. Plumb faced, Fig. A.	Natural slope 3 to 1. Plumb backed, Fig. B.	Natural slope 3 to 1. Front batter 1 in 12 Fig. C.	Water. Plumb faced, Fig. A.	Water. Plumb backed, Fig. B.	Water. Front batter 1 in 12, Fig. C.
4	1·50	1·50	1·50	1·50	1·50	1·50	2·11	1·50	1·85	2·55	1·29	2·29	2·77	1·42	2·51
6	1·50	1·50	1·50	2·11	1·50	1·71	3·56	1·91	3·16	4·31	2·38	3·91	4·75	2·65	4·35
8	1·50	1·50	1·50	3·08	1·62	2·74	4·97	2·78	4·44	5·96	3·40	5·43	6·55	3·80	6·09
10	1·93	1·50	1·50	3·89	2·24	3·43	6·40	3·67	5·74	8·36	4·41	6·95	8·4	4·0	8·05
12	2·55	1·50	1·75	4·97	2·79	4·17	7·83	4·55	7·03	10·0	5·33	8·46	10·2	4·9	9·45
14	3·03	1·59	2·10	5·96	3·40	4·03	9·26	5·43	8·29	10·9	6·45	9·98	12·1	5·9	11·1
16	3·65	1·97	2·59	6·95	4·51	5·99	10·7	6·32	9·67	12·7	7·44	11·6	13·9	6·9	12·0
18	4·20	2·31	3·00	7·72	4·84	6·55	12·1	7·20	10·9	14·2	8·49	13·0	14·7	7·8	14·5
20	4·75	2·65	3·42	8·82	5·16	7·49	13·5	8·09	12·1	15·8	9·46	14·4	17·5	8·7	16·1
22	5·99	3·15	4·20	11·07	6·06	9·42	16·9	9·46	15·4	19·7	11·1	18·3	21·8	12·3	20·4
24	6·60	3·51	4·75	11·99	6·63	10·2	18·4	10·32	16·8	21·5	12·2	20·0	23·7	13·4	22·2
26	7·21	3·86	5·21	13·21	7·34	11·3	20·1	11·4	18·3	23·0	13·3	21·8	25·7	14·6	24·1
28	7·82	4·22	5·67	14·19	7·91	12·2	21·5	12·22	19·7	25·2	14·3	23·4	27·7	15·7	25·9
30	8·44	4·57	6·12	15·17	8·48	13·0	24·1	12·51	21·1	27·9	15·4	25·2	29·6	16·8	27·7



Table for Value of b. for Stone masonry in retaining walls.

Height.	Earth.												Water.		
	Natural slope ½ to 1.			Natural slope 1 to 1.			Natural slope 2 to 1.			Natural slope 3 to 1.					
	Plumb faced, Fig. A.	Plumb backed, Fig. B.	Front batter 1 in 12, Fig. C	Plumb faced, Fig. A.	Plumb backed, Fig. B.	Front batter 1 in 12, Fig. C.	Plumb faced, Fig. A.	Plumb backed, Fig. B.	Front batter 1 in 12, Fig. C.	Plumb faced, Fig. A.	Plumb backed, Fig. B.	Front batter 1 in 12, Fig. C.	Plumb faced, Fig. A.	Plumb backed, Fig. B.	Front batter 1 in 12, Fig. C.
4	1·50	1·50	1·50	1·50	1·50	1·50	1·89	1·50	1·63	2·11	1·50	1·85	2·55	1·50	2·29
6	1·50	1·50	1·50	1·84	1·50	1·50	3·10	1·63	2·70	3·76	2·03	3·34	3·98	2·17	3·58
8	1·50	1·50	1·50	2·70	1·15	2·17	4·42	2·44	3·89	5·23	2·94	4·70	5·85	3·33	5·32
10	1·67	1·50	1·50	3·55	1·91	2·89	5·41	3·05	4·75	6·73	3·87	6·07	7·50	4·35	6·84
12	2·20	1·50	1·50	4·41	2·50	3·61	6·95	4·01	6·15	8·27	4·82	7·47	9·15	5·37	8·35
14	2·68	1·50	1·75	5·28	2·98	4·35	8·27	4·82	7·34	9·75	5·71	8·82	10·5	6·18	9·57
16	3·17	1·67	2·11	6·15	3·50	5·09	9·48	5·57	8·42	11·2	6·66	10·1	12·4	7·41	11·3
18	3·65	1·97	2·45	7·00	4·03	5·80	10·8	6·39	9·60	12·7	7·54	11·5	14·0	8·36	12·8
20	4·13	2·26	2·80	7·85	4·57	6·52	12·0	7·13	10·7	14·2	8·49	12·9	15·6	9·38	14·3
22	4·64	2·58	3·18	8·70	4·95	7·24	13·3	7·95	11·8	15·7	9·40	14·2	17·3	10·4	15·8
24	5·14	2·89	3·54	9·57	5·65	7·97	14·6	8·25	13·0	17·2	10·3	15·6	18·9	11·4	17·3
26	5·63	3·20	3·90	10·5	6·15	8·77	16·0	9·00	14·3	18·7	11·3	17·0	20·6	12·4	18·9
28	6·07	[illegible]50	4·21	11·6	6·65	9·44	17·3	9·75	15·4	20·1	12·2	18·2	22·1	13·4	20·2
30	6·62	3·80	4·62	13·2	7·20	10·2	18·6	10·4	16·6	21·7	13·1	19·7	23·9	14·5	21·9

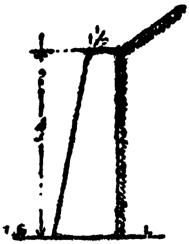
WING WALLS AND RETAINING WALLS.

All wing walls start from the top of the head or the road level and splayed at an angle of 120° in the direction of bridge.

The thickness at any height $= \frac{4}{10}$ of that height.

For example, if a point N is 18 feet high, the thickness $=18 \times \frac{4}{10} = 7{\cdot}2$. The top thickness should be not less than 2 feet but for smaller bridges it may be 18″ to 20″. The thickness should be $\frac{1}{3}$th of the height throughout, *i.e.*, $\frac{1}{12}$ at top and $\frac{1}{3}$ at base. The batter on the front should be 1 in 12.

SURCHARGED WALLS.



If the wall is surcharged, increase the height *h* according to the following rule and find the value of *b* from the table:

For slope 1 to $\frac{1}{2}$ multiply by 1·9
slope 1 to 1 multiply by 1·7
slope 1 to 2 multiply by 1·4
slope 1 to 3 multiply by 1·3

Width of foundation:—

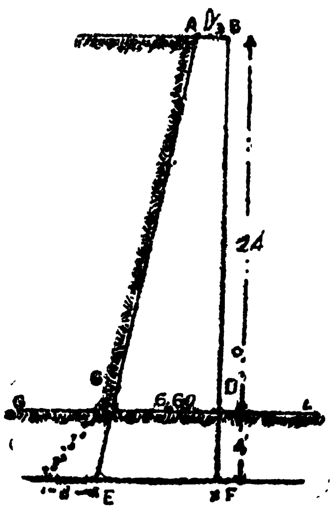
Let ABCD be a retaining wall. Produce AC till it meets the foundation line at E. Measure E F by scale and give offsets =d in the following way:—

Find out the area of ABEF and multiply by 120 if brick masonry and by 150 if it is stone masonry.

Let the result=W.

Let x=safe load on foundations.

In the above case the resultant passes $\frac{1}{3}$ from the base and hence the retaining wall will fail if the offset is not given.



Upto 20′ height, $d = \frac{2}{3} \times \frac{W}{x} - \frac{y}{8}$.

Between 20′ and 30, $d = \frac{2}{3} \times \frac{W}{x} - \frac{y}{6}$.

If stone masonry up to 30, $d = \frac{2}{3} \times \frac{W}{x} - \frac{y}{6}$

As soon as *d* is found, lay this out in offsets as shown in the diagram by dotted lines.

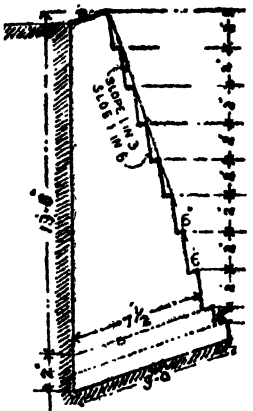
Example.—Let the height of wall = 24 feet, natural slope of earth $\frac{1}{2}$ to 1 and the masonry is of brick with a vertical face and batter at the back.

According to table for Fig. A we find 6·6 for 24′ height

then 24 : 6·6 : : 28 : y, $y=7\cdot7'$ } (depth of foundation = 4 feet)

$$\text{area E A B F}=\frac{7\cdot7\times1\cdot5}{2}\times28=128\cdot8$$

$$W=128\cdot8\times120=15456\text{ lbs.}$$



$$d=\tfrac{2}{3}\times\frac{W}{x}-\frac{y}{6}\ \text{When } x=1\text{ ton per sq. ft.}$$

$$d=\tfrac{2}{3}\times\frac{15456}{2240}-\frac{7\cdot7}{6}=3\cdot3\text{ ft.}$$

∴ Total width at foundation level $=7\cdot7+3\cdot3=11$ feet.

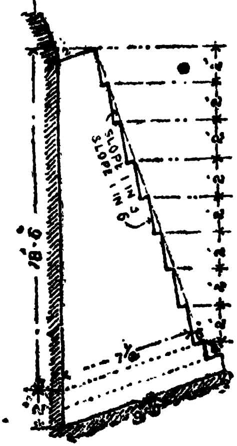
Dry Retaining Walls and Dry Breast Walls.

Top width 2′, back vertical, front batter 4 to 1, steps at back 3″, all **courses normal to the face and foundation at right angles to the face batter.**

The following is a section of breast wall. When the height exceeds 16′, it is advisable to provide 2 or 3 courses in lime at every 2 feet height of the wall to give it more strength and durability.

No stone should be used which is less than half a cubic foot in size. The bed of each stone must be not less than one and a half times its height, and at least half the stones should tail into the wall twice their height. Stones must break joint by at least half the height of the course.

Through bond stones should be inserted in each course at five feet intervals, and all such stones must be clearly marked with tar or paint on the inside face of the wall.



ARCHES.

Thickness of arches :—

A rough rule for quickly determining the thickness of an arch ring in a masonry culvert is $\cdot17\times\sqrt{R}$ for one span arch and $\cdot12\sqrt{R}$ for continuous arches. In general, thickness of arch $=n\times\sqrt{R}$ where n has the following values :—

Arch with one span :—

n = ·35 for Stone arches.

n = ·45 for Brick arches.

Arch with more than one span :—

n = ·3 for Stone arch.

n = ·4 for Brick arch.

Table of Thickness of Arches of one Span.

Radius of curvature.	Stone arch.	Brick arch.	Radius of curvature.	Stone arch.	Brick arch.	Radius of curvature	Stone arch.	Brick arch.
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
2	·49	·67	9	1·05	1·35	20	1·56	2·01
2½	·55	·71	10	1·11	1·42	22	1·64	2·11
3	·61	·78	11	1·16	1·49	24	1·71	2·20
3½	·65	·84	12	1·21	1·56	25	1·75	2·25
4	·70	·90	13	1·26	1·62	30	1·92	2·46
4½	·74	·95	14	1·31	1·68	35	2·07	2·66
5	·78	1·01	15	1·36	1·74	40	2·21	2·84
5½	·82	1·05	16	1·40	1·80	45	2·35	3·01
6	·86	1·10	17	1·44	1·86	50	2·47	3·18
7	·92	1·19	18	1·48	1·91	55	2·63	3·38
8	·99	1·27	19	1·52	1·96	60	2·71	3·48

Table of Thickness of Arches of more than one Span.

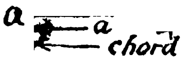
Radius of curvature.	Stone arch.	Brick arch.	Radius of curvature.	Stone arch.	Brick arch.	Radius of curvature	Stone arch.	Brick arch.
2	·42	·60	9	·90	1·20	20	1·34	1·79
2½	·47	·64	10	·95	1·26	22	1·41	1·88
3	·52	·69	11	1·00	1·33	24	1·47	1·96
3½	·56	·75	12	1·04	1·38	25	1·50	2·00
4	·60	·80	13	1·08	1·44	30	1·64	2·19
4½	·64	·85	14	1·12	1·50	35	1·78	2·37
5	·67	·90	15	1·16	1·55	40	1·90	2·53
5½	·71	·94	16	1·20	1·60	45	2·01	2·68
6	·74	·98	17	1·24	1·65	50	2·12	2·83
7	·80	1·06	18	1·27	1·70	55	2·22	2·97
8	·85	1·13	19	1·32	1·74	60	2·33	3·10

Spandril walls.—The walls built on the top of the arch rings up to the level of the road way.

Table of Rise of Arches.

Angle.	Rise/span =	Angle.	Rise/Span =	Angle.	Rise/Span =	Angle.	Rise/Span
60°	·134	100°	·233	130°	·319	160°	·420
70°	·158	110°	·260	140°	·350	170°	·458
80°	·182	120°	·289	150°	·384	180°	·500
90°	·207	..	..	..	..	..	..

Useful Dimensions for Arches.



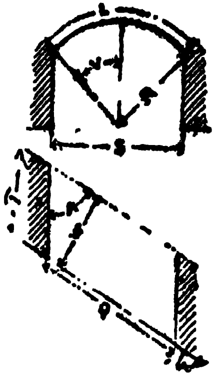
Rise/Chord	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	5
Radius = Chord ×	·5	·54	·625	·725	1·30
Arc a c b = Chord ×	1·57	1·27	1·16	1·10	1·036
Area a d c + b e c = Chord × rise ×	·22	·27	·30	·31	·33
Area a c b a = Chord × rise ×	·785	·73	·70	·69	·67

$$\text{Radius} = \frac{r^2 + a^2}{2\,r}$$

Skew Arches.

A skew arch is one whose axis is not at right angles to its face, or whose two centre lines in plan are not perpendicular to each other.

A skew-back is the sloping surface against which the springing of an arch rests.



A=Angle of skew.

R=Radius of arch.

S= Span on the squares.

W=Width on the square.

V=½ Angle of arch.

Q=Span on the skew.

T=Length of impost.

$$Q = \frac{T}{W} \times S$$

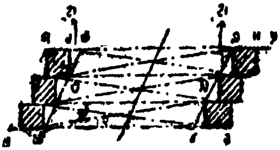
L=length of arc=·0349 RV

In case of semicircular arches:—

$$L = 1{\cdot}5705S = \frac{S}{2} \times 90 \times {\cdot}0349 = 90 \times R \times {\cdot}0349$$

(*Molesworth*).

Method of striking a skew arch for small



Let A B be the face of the arch and C D the span and H C the thickness of arch and A C and B D the thickness of abutment on front face.

Bring the masonry of abutments C A E J and D B F K to springing line and fix the thickness of arch C H on it. Draw C M perpendicular in such a way that the offset M N=1 foot. Similarly make D P=1 foot. Draw P Q perpendicular at P, joining the line of abutment D K at Q and proceed as in sketch, care being taken that all such arches are in bond.

The generally accepted method for the skew arch is to make a portion of a hollow cylinder in which the arch stones are laid in parallel spiral courses and with their beds worked in such a way that in any section of the cylinder perpendicular to its axis the lines formed by their intersection with the plane of section shall radiate from the axis of the cylinder. By this method the soffit of each stone will be a portion of a cylindrical surface and the twist of the beds will be uniform all over the arch. Therefore, knowing once for all the angle of twist, the working of the stones is not very much more difficult than with the ordinary square arch.

Dimensions of Semicircular Arched Culverts for Railways.

Items.	Light type. Spans.				Heavy type. Spans.				Extra Heavy type. Spans.			
	3′	4′	5′	6′	3′	4′	5′	6′	3′	4′	5′	6′
	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
Heights.												
Ground to springing of arch	2-0	2-0	2-6	3-0	2-0	2-0	2-6	3-0	2-0	2-0	2-6	3-0
Rise of arch	1-6	2-0	2-6	3-0	1-6	2-0	2-6	3-0	1-6	2-0	2-6	3-0
Thickness of arch	0-9	0-10	0-11	1-0	1-0	1-1	1-2	1-3	1-0	1-1	1-2	1-3
Earth cushion above arch	1-9	2-2	2-1	2-0	1-6	1-11	1-10	1-9	1-6	1-11	1-10	1-9
Total, ground to top of parapet (excluding coping).	6-0	7-0	8-0	9-0	6.0	7-0	8-0	9-0	6-0	7-0	8-0	0-0
Thickness.												
Pier, from ground to springing	2-0	2-3	2-3	2-6	2-6	2-9	2-9	3-0	2-6	2-9	2-0	3-0
Abutment, at ground level	2-0	2-3	2-9	3-0	2-[illegible]	2-3	2-9	3-0	2-1	2-6	2-10½	3-3
Arch.												
Radius of intrados	1-6	2-0	2-6	3-0	1-6	2-0	2-6	3-0	1-6	2-0	2-6	3-0
Thickness of arch	0-9	0-10	0-11	1-0	1-0	1-1	1-2	1-3	1-0	1-1	1-2	1-3

Light type will be used where foundations are strong and good earth for embankment.
Heavy type will be used where foundations are strong and earth is of average quality.
Very heavy type will be used where neither foundations nor hearth is good.

Dimensions of Segmental Arched Culverts for Railways.

Items.	Light Type.								
	Spans.								
	6′	8′	10′	12′	15′	16′	18′	20′	24′
Heights.	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
Ground to springing of arch ..	3-0	4-0	5-0	6-0	7-6	8-0	9-0	10-0	12-0
Rise of arch	2-0	2-8	3-4	4-0	5-0	5-4	6-0	6-8	8-0
Thickness of arch	1-0	1-1	1-2	1-3	1-4½	1-5	1-6	1-7	1-9
Earth cushion above arch ..	2-0	2-3	2-6	2-9	3-1½	3-3	3-6	3-9	4-3
Total, ground to top of parapet (excluding coping).	8-0	10-0	12-0	14-0	17-0	18-0	20-0	22-0	26-0
Thickness.									
Pier from ground to springing ..	2-6	2-9	3-0	3-3	3-6	3-6	3-6	4-0	4-6
Abutment. at ground level ..	3-0	3-9	4-3	5-0	6-0	6-3	7-9	7-9	9-0
Arch.									
Radius of intrados	3-3	4-4	5-5	6-6	8-1½	8-8	9-9	10-10	13-0
Thickness of arch	1-0	1-1	1-2	1-3	1-4½	1-5	1-6	1-7	1-9
Height for face of skew back ..	0-6	0-6	0-7½	0-7½	0-9	0-9	0-10½	0-10½	1-0

Dimensions of Segmental Arched Culverts for Railways—concld.

Heavy Type.									Extra Heavy Type.								
Spans.									Spans.								
6′	8′	10′	12′	15′	16′	18′	20′	24′	6′	8′	10′	12′	15′	16′	18′	20′	24′
′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
3-0	4-0	5-0	6-0	7-6	8-0	9-0	10-0	12-0	3-0	4-0	5-0	6-0	7-6	8-0	9-0	10-0	12-0
2-0	2-8	3-4	4-0	5-0	5-4	6-0	6-8	8-0	2-0	2-8	3-4	4-0	5-0	5-4	6-0	6-8	8-0
1-1½	1-3	1-4½	1-6	1-8¼	1-9	1-10½	2-0	2-3	1-3	1-5	1-7	1-9	2-0	2-1	2-3	2-5	2-9
1-10½	2-1	2-3½	2-6	2-9¾	2-11	3-1¼	3-4	3-9	1-9	1-11	1-2	2-3	2-0	2-7	2-9	2-11	3-3
8-0	10-0	12-0	14-0	17-0	18-0	20-0	22-0	26-0	8-0	10-0	12-0	14-0	17-0	18-0	20-0	22-0	26-0
2-9	3-0	3-3	3-6	4-0	4-3	4-6	4-9	5-3	2-9	3-3	3-6	4-	4-6	4-9	5-0	5-6	6-3
3-0	3-9	4-3	5-0	6-0	6-3	7-0	7-9	9-0	3-3	4-0	4-9	5-6	6-7½	7-0	7-9	8-6	10-0
3-3	4-4	5-5	6-6	8-1½	8-8	9-9	10-10	13-0	3-3	4-4	5-5	6-6	8-1½	8-8	9-9	10-10	13-0
1-1½	1-3	1-4½	1-6	1-8¼	1-9	1-10½	2-0	2-3	1-3	1-5	1-7	1-9	2-0	2-1	3-3	2-5	2-9
0-6	0-6	0-7½	0-7½	0-9	0-9	0-10½	0-10½	1-0	0-6	0-6	0-7½	0-7½	0-9	0-9	0-10½	0-10½	1-0

CENTERING.

A centre is a temporary structure of timber for supporting an arch while it is being built.

It consists of parallel frames called ribs placed 1 to 6 feet apart and covered with planks laid close called laggings upon which the arch stones directly rest.

Avoid mortise and tenon or other expensive joints. Avoid long nails and spikes and instead use iron gusset plates, bolts, dogs, coach screws or the like.

Striking centres.—When centering has to be removed or "struck" some means of "easing" must be arranged before lowering them clear of the finished work. This is done by means of wedges. Their usual size is 12″ to 24″ long by 6″ wide, slope $\frac{1}{8}$ only, the object being to lower from 2″ to 6″ very gradually. The alternatives are screw jacks and sand boxes.

The proper time for striking centres is a disputed point among different Engineers; some are of opinion that it should be done as soon as the arch is finished and sufficiently backed up; while others are of opinion that the mortar should be given time to harden.

For a 50 foot span not more than $\frac{1}{2}$″ easing should be done in one day; lowering by $\frac{1}{8}$th of an inch.

With ordinary lime, centres should be eased while mortar is still green, as soon as the arch is loaded to stability and struck on an average from 5 to 8 days.

Centering for concrete should not be disturbed for at least 15 days.

Where a series of spans are arched, the centering of at least two should be left in whilst the third span is being built and not removed till this span is complete and set.

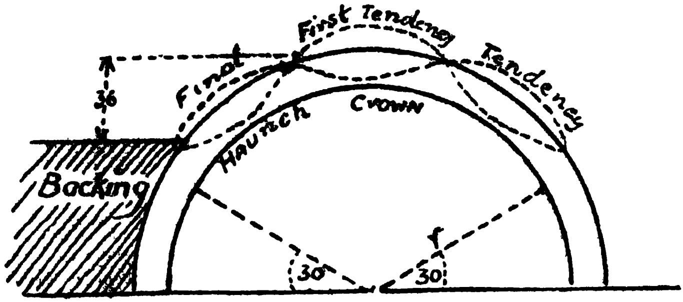
Thickness of lagging (Trautwine).

Dist. apart of frames, feet	Span of Centre in feet.					
	10	20	50	100	150	200
	Inches.					
6	$3\frac{1}{4}$	$3\frac{5}{8}$	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$
5	$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{3}{8}$	$3\frac{5}{8}$	$3\frac{7}{8}$	4
4	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3
3	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	2
2	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$

NOTE.—Thickness of close lagging not to bend more than $\frac{1}{8}$ inch.

It is better to increase the number of ribs than the thickness of laggings.

Loading Centres.—The load during construction is gradually increased from the springing to the crown.



Height of backing before striking centering

$x = \sqrt{rc}$

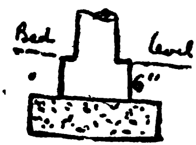
Centering for Skew Arches.

The centres upon which Skew Arches are constructed will be different from those for square ones, and are a little more difficult to make because the ribs should be placed parallel to the face and not to the centre line of roadway. The laggings have to be very carefully fixed and planned up true to templet cut to the curve of the soffit, and upon this depends the accuracy of the work. The laggings are made close, and upon them the coursing and heading joints are marked. To do so the face lines are drawn and bisected and a bevel line drawn along the crown of the centering from centre to centre of each face. Upon a long, thin straight edge the divisions of the heading spiral are transferred from the rod previously prepared as stated. The length of the straight edge is equal to the distance from impost to crown of arch. Starting at the end of one of the imposts the flexible straight edge is bent round the centering and a series of heading spirals drawn from impost to impost through the divisions on the centre line and corresponding lines on the checks on the springing stones. The divisions on the straight edge are transferred to the heading spirals, making sure that the centre line of the crown passes through the centre of a division in every case.

Having thus found those points, the coursing spirals are drawn, which will coincide with the coursing joints in the soffit of the arch. Finally the heading points are marked and the number of each arch stone chalked on to facilitate laying. The face joints, unlike the heading joints, are not perpendicular to the curve of the soffit, but will make various angles with the coursing joints.

Table of Bridge dimensions required for a 15 tons roller.

Span	Arch		Thickness of pier.		Width of pier foundation.														Depth of pier foundation.	
					90°							75°								
					Height of piers.							Height of piers.								
	90°	75°	90°	75°	1	2	3	4	5	6	7	1	2	3	4	5	6	7	90°	75°
2	·8	·8	1·3	1·3	2	2·25	..	..	..	..	..	2·25	2·5	..	..	..	..	..	2·0	..
3	·8	·8	1·3	1·7	2·25	2·75	3·0	..	..	..	..	2·5	3·0	3·25	..	..	..	..	2·0	2·0
4	·8	1·3	1·7	1·7	2·5	3·0	3·25	3·5	..	..	..	2·75	3·25	3·5	3·75	..	..	..	2·0	2·0
5	1·3	1·3	1·7	2·1	2·75	3·25	3·5	3·75	..	..	..	2·75	3·5	3·75	4·0	4·25	..	..	2·0	2·5
6	1·3	1·3	2·1	2·1	3·0	3·5	3·75	4·0	4	..	..	3·0	3·75	4·0	4·25	4·5	4·75	..	2·25	2·25
7	1·3	1·3	2·1	2·1	3·0	3·75	4·0	4·25	4·25	4·5	..	3·25	4·0	4·25	4·5	4·75	5·0	5·25	2·25	2·25
8	1·3	1·3	2·1	2·5	3·25	3·75	4·25	4·5	4·5	4·75	5·0	3·5	4·0	4·5	4·75	5·0	5·25	5·5	2·5	2·5
9	1·3	1·7	2·5	2·5	3·50	4·0	4·5	4·75	4·75	5·0	5·25	3·5	4·25	4·75	5·0	5·25	5·5	5·75	2·5	2·75
10	1·7	1·7	2·5	2·5	3·50	4·25	4·5	5·0	5·0	5·25	5·5	3·75	4·5	5·0	5·25	5·5	5·75	6·0	2·75	2·75
11	1·7	1·7	2·5	3·0	3·75	4·75	4·75	5·0	5·25	5·5	5·75	3·75	4·5	5·0	5·5	5·75	6·0	6·25	2·75	3·0
12	1·7	1·7	3·0	3·0	3·75	4·75	4·75	5·25	5·5	5·75	6·0	4·0	4·75	5·25	5·5	6·0	6·25	6·5	3·0	3·0
13	1·7	1·7	3·0	3·0	4·0	4·75	5·0	5·5	5·5	6·0	6·25	4·0	5·0	5·5	5·75	6·0	6·5	6·75	3·0	3·25
14	1·7	1·7	3·0	3·0	4·0	4·75	5·25	5·5	5·75	6·0	6·25	4·25	5·0	5·5	6·0	6·25	6·5	7·0	3·25	3·25
15	1·7	2·1	3·0	3·0	4·25	4·75	5·5	5·75	6·25	6·5	6·75	4·5	5·25	5·57	6·25	6·5	6·75	7·25	3·25	3·5



NOTE.—(1) The pier will extend to 6" below florr level and will be stepped ·8 feet in this height.

(2) The earth and metalling over crown of arch should be in all at least 1½ feet.

REINFORCED BRICKWORK.

(BY A. K. DATTA, B.E., C.E., A.M.I.E., CONSULTING ENGINEER).

Reinforced brickwork is a general term for brickwork built in cement mortar, with steel or iron, in the form of rods, bars, or hoop iron, thoroughly embedded in joints of cement mortar or cement concrete ; the two materials , *viz.*, brickwork and steel are so combined as to produce a more economical material than either acting alone.

The underlying principle in all reinforced work whether of concrete or of brickwork is that concrete or brickwork takes up compression and steel reinforcements take up tension. Wherever there is any tension steel is to be provided.

Cement concrete is stronger and stiffer than brickwork in cement, but the former is much more costly than the latter as the consumption of cement is nearly double and the centering or shuttering is more expensive. Brickwork is much more plastic than cement concrete and is much less affected by heat or cold.

Adhesion between Concrete and Steel :—

In a reinforced concrete or brickwork structure the tensile stresses developed are taken by the steel and the compressional ones by concrete or brickwork. The two materials, *viz.*, steel and concrete or brickwork will bear their share of stresses, so long as there is no relative movement between the two ; if that be otherwise, the concrete or brickwork structure (say a beam) is like one cast with holes with rods inserted in them. The strength of the beam will be no greater with the rods than one without them, because relative movement between steel and concrete or brickwork would then be possible. In all reinforced structures good bond strength between steel and cement concrete or mortar is absolutely essential.

In case of concrete that is taken as 100 lbs. per sq. inch as safe. In case of reinforced brickwork with round rods the same value may be taken. In case of flat bars or hoop irons the value should not exceed 60 lbs. per sq. inch.

Brief Review of Reinforced Brickwork Construction :—

(*a*) *Materials for construction :—*

(1) First-class bricks.
(2) Portland Cement.
(3) Sand.
(4) Brick or stone chips ($\frac{1}{2}''$ gauge) in case of concrete.
(5) Mild steel rods for reinforcements.

(*b*) *Materials for centering :—*

(1) Supports for centering, as joists, sal sleepers, ballahs, plank ribs, small sections of rails and similar things.
(2) Planks, iron sheets on frame work, thick bamboo pieces or thin bamboo challies, sal farrahs (side planks of sal logs sawn) and similar things spread over the supports.
(3) Earth rubbish, sand, spread over the planks to make the surface smooth with a little camber at centre. This camber is kept usually as $\frac{1}{2}''$ to $\frac{3}{4}''$ per 10 ft. of span.

(4) A thin coat of weak lime plaster is often used on the centering for a smooth surface as it is not easily disturbed during construction.

(c) *Procedure for construction :—*

(1) A centering is first constructed.

(2) Reinforced brickwork structure is constructed over it.

(3) When the cement mortar of the structure had set hard the centering is removed.

(4) The structures are thoroughly watered for two weeks after construction.

The centering for the slabs are usually removed 6 or 7 days after construction and in case of beams 2 to 4 weeks according to the nature of the beams.

(5) The proportion of cement mortar usually adopted is $2\frac{1}{2}$ or 3 sand to 1 cement by volume, in case of good coarse sand 3 to 1 proportion can be used. The cement mortar should have a tensile strength of 160 lbs. per sq. inch (preferably 200 lbs. per sq. inch) in 7 days.

(6) The proportion of the concrete should be rich in mortar, 1 : 2 : 3 or 1 : $2\frac{1}{2}$: $3\frac{1}{2}$ or 4 are usually adopted in reinforced brickwork.

(d) *Theory of construction :—*

(1) Steel takes up tension in all cases. For positive bending moments in beams and slab, steel is used at bottom and for negative bending moment as for fixing of supports at ends, steel is used at top of the beam or slab. When the shear stress in the beams or slabs runs up very high, say above 20 or 25 lbs. per sq. inch, vertical stirrups are used for taking the shear.

(2) Brick in cement takes care of the compression, and part of the shear.

(e) *Essential features for construction :—*

(1) A suitable economical design.

(2) Careful supervision.

(3) Good materials.

(f) *Special points of supervision :—*

(1) Rigidity of centering,

(2) facility for its removal,

(3) steel placed at the required position, thoroughly embedded in cement mortar or cement concrete. The cover of mortar on the steel from the bottom sides should not be less than $\frac{3}{4}''$ and cover on rods from the side bricks should not be less than $\frac{3}{8}''$.

(4) All joints must be full and no voids are to be left.

(5) Bricks are thoroughly wetted and washed clean of kiln dust before use.

(6) All mortars must be mixed first dry and then wet. Only so much dry mortar is to be mixed up with water which will be used up in the work within 15 minutes from the time of mixing.

(7) Reinforced brickwork should be kept moist continuously for 2 weeks and after that occasional watering should be done.

(8) Special care must be taken to secure the joints of steel very sound and intact. Lapping of rods should be 40 diameters with hooks at ends. Hooking like that as done in telegraph wires with an extra lapping piece is also quite reliable.

(*g*) *Applications in construction* :—

Reinforced brickwork lintels.— very extensively used throughout India.

Reinforced brickwork Slabs :—extensively used at the new Capital Works, Patna, at the Benares Hindu University Works, Benares, at the new Delhi Construction, Delhi, at Sir Ganga Ram's Hydro-Electric Works at Renala Khurd, Punjab, and in any number of places throughout India.

Reinforced brickwork beams :—very extensively used at the Benares Hindu University Works; at many places at Patna, Lucknow, Cawnpore and other places R. B. Beams had been extensively used.

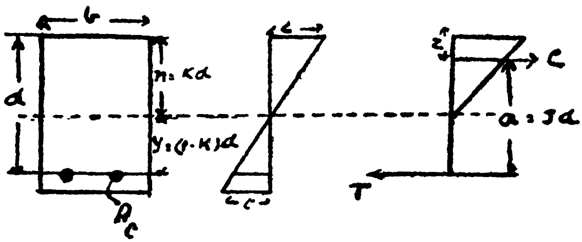
Reinforced brickwork partition walls :—in extensive use throughout India.

Reinforced Brickwork Girders :—many heavy girders had been constructed at the Benares Hindu University, the heaviest is for the Arts College Hall on 36 ft. designed for a load of 153 tons. 4 R. B. C. girders are being constructed for a hall 60′ 6″ × 77′ each designed for a load of 174 tons on 63 ft. effective span.

Reinforced brickwork pitching :—had been extensively used at Sir Ganga Ram's Hydro-Electric Power House Channel at Renala Khurd.

Reinforced brickwork syphon :—has been constructed on L. B. D. Canal at Renala Khurd, etc , etc., etc.

Formulæ for Rectangular Beams :—



For position of neutral axis............

Neutral axis.

$$K = \frac{n}{d}$$

$$n = \sqrt{(pm)^2 - 2pm} - pm \quad .. \quad .. \quad .. \quad (1)$$

Lever arm $= a = jd = d\left(1 - \frac{k}{3}\right) = d - \frac{n}{3} \quad .. \quad (2)$

Resisting Moment = M = sectional area of steel × maximum stress in steel × lever arm

$$= A_t \cdot t \cdot a$$

$$= A_t \cdot t \cdot jd \cdot \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$n = t \cdot pjbd^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$M = \tfrac{1}{2} c \cdot kjbd^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Fibre stress for given bending moment :—

$$t = \frac{B}{pjbd^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$c = \frac{2B}{kjbd^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\frac{t}{c} = \frac{k}{2p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Steel ratio for given working stresses ;—

$$p = \frac{1}{2\frac{t}{c}\left(\frac{t}{mc} + 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

General relation between stresses, bending moments, etc :—

$$\frac{t}{my} = \frac{B}{I} = \frac{c}{n} \text{ where } y = (d - n) \quad \ldots\ldots\ldots\ldots (9)$$

$$\text{Moment of inertia} = \frac{bn^2}{2}\left(d - \frac{n}{3}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

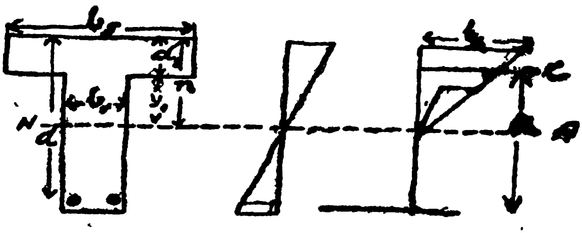
$$\text{Intensity of shear stress} = s = \frac{S}{ab} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$\text{Intensity of bond stress} = f = \frac{\text{vertical shear}}{\text{total perimeter of rods} \times \text{lever arm.}}$$

$$= \frac{S}{O \cdot a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Sectional area of steel required for stirrups in a certain section of

$$\text{beams} = \frac{B_1 - B_2}{a \times f_s} = \frac{\text{difference of bending moments.}}{\text{lever arm} \times \text{safe shear stress in steel}} \quad (13)$$



T Beam with Single Reinforcement

Formulæ for T beams :—

Case I—Neutral axis is in the flange :—

The formulæ for the rectangular beams should be used.

Case II.—Neutral axis is in the stem :—

The following formulæ, neglect the compression in the stem.

The position of the neutral axis :—

$$n = kd = \frac{2mA_t d + bd_s^2}{2mA_t + 2bd_s} \quad \text{......(1)}$$

For lever arm :—

Position of resultant compression :—

$$Z = \frac{3kd - 2d_s}{2kd - d_s} \times \frac{d_s}{3} \quad \text{......(2)}$$

Arm of resultant couple :—

$$= jd = d - z \quad \text{......(3)}$$

For resisting moment :—

$$M = A_t \; t. \; jd = A_t \times t \, (d - z) \quad \text{......(4)}$$

For stresses :—

$$t = \frac{M}{A_t \, . \, jd} \quad \text{......(5)}$$

$$c = \frac{M \cdot kd}{bd_s (kd - \frac{1}{2}d_s) \, jd} \quad \text{......(6)}$$

$$\frac{c}{t} = \frac{k}{m \, (1 - k)} \quad \text{......(7)}$$

Where

a = lever arm or arm of the resisting couple formed by the compressive and tensile stresses in a beam.

b = breadth of a rectangular beam parallel to neutral axis.

b_s = effective breadth of a slab in a tee beam.

d = effective depth of beam (distance between the compression edge and the centre of the tensile reinforcements).

d_s = total depth of a slab in a tee beem.

c = Intensity of compressive stress in concrete or brickwork.

t = Intensity of tensile stress in steel.

j = ratio of lever arm and effective depth $= a/d$.

k = ratio of depth to neutral axis from compression edge to effective depth $= n/d$.

m = modulus ratio between steel and concrete or brickwork $= \frac{E_s}{E_c}$

n = depth to neutral axis from the compression edge.

p = percentage of steel $= \frac{A_t}{b_d} \times 100.$

y = the distance between neutral axis and centre of steel.

A_t = Sectional area of steel in tension in beams.

B = Bending moment.

I = Moment of inertia.

M = Resisting moment or moment of resistance of internal stresses in a beam at a given cross section.

W = weight or load.

z = distance between the compression edge and the line of resultant compression in a tee beam.

o = Perimeter of the reinforcing rods at any section.

Values for Reinforced Concrete

$$\text{Modulus ratio} = m = \frac{E_s}{E_c} = 15.$$

Steel in tension = 16000 lbs. per sq. inch.
Steel in shear (diagonal tension) = 16000 lbs. per sq. inch.
Steel in compression :—16000 lbs. per sq. inch.
Concrete in Compression (transverse) :—600 lbs. per sq inch.
Concrete in compression (columns) :—500 lbs. per sq. inch.
Concrete in shear :—60 lbs. per sq. inch.
Concrete in diagonal tension :—40 lbs. per sq. inch,
Adhesion of concrete to steel :—100 lbs. per sq. inch.

Reinforced slabs are designed as beams, considering its width as 1 ft. reinforcements, etc., are designed per ft. width.

Safe stress, etc., for Reinforced Brickwork.

Modulus ratio = $m = E_s/E_b = 60$ (varies between 40 to 60 according to the quality of bricks and mortar used).

Steel in tension................=16000 lbs. per sq. inch.
Steel in shear (diagonal tension....16000 lbs. per sq. inch.
Brickwork in compression (bending)... 250 lbs. per sq. inch.
Ditto ditto with hoop binders..300 lbs. per sq. inch.
Ditto ditto for thin slabs as 3″ to 8″..300 lbs. per sq. inch.
Brickwork in direct compression...10 tons per sq. foot or 176 lbs. per sq. (columns) inch.
Ditto with hoop binders 300 lbs. per sq. inch.
Brickwork in diagonal tension.........25 lbs. per sq. inch (for 2½ to 1 cement mortar).
Adhesion of brickwork (2½ to 1) to steel (Round rods) 100 lbs. per sq. inch.

m=15.

P=%	$k = \frac{n}{d}$	$j = \frac{a}{d}$	$\frac{M}{bd^2}$ with t=16000 lbs. per sq. in.	$\frac{F_s}{F_b}$	F_b
·2	·22	·93	29·8	55	290
·4	·29	·90	57·7	36·3	440
·6	·34	·89	85·5	28·3	565
·8	·38	·87	112	23·8	670
1·0	·415	·86	138	20·8	770
1·5	·48	·84	202	16	1000
2·0	·54	·82	263	13·5	1190

m=60

P=%.	$k = \frac{n}{d}$	$j = \frac{a}{d}$	$\frac{M}{bd^2}$ with t=16000 lbs. per sq. in.	$\frac{F_s}{F_b}$	F_b
·2	·384	·872	28·0	96	167 lbs. per
·3	·445	·851	41·0	75	213 sq. in.
·4	·492	·836	53·6	62	258
·5	·53	·823	65·8	54	296
·6	·56	·813	78·0	47	340
·7	·58	·807	90·4	42·5	376
·8	·61	·797	102·2	38	420
·9	·63	·79	114·0	35	457
1·0	·65	·783	125·5	33	485

REINFORCED BRICKWORK LIME BRICKWORK SLABS FOR ROOFS AND FLOORS OF BUILDINGS.

(R. B. L. B. SLABS.)

(PATENT.)

R. B. L. B. SLABS provide a very cheap and efficient system of roofing and flooring for buildings. They are much cheaper than reinforced brickwork or reinforced concrete slabs. They consist of alternate ribs of brickwork in cement and brickwork in lime with the reinforcing rods embedded in cement mortar or cement concrete joints. The economy in these slabs is due to the great saving in cement in the construction of the slabs; R. B. L. B. Roofs are absolutely watertight.

In reinforced brickwork and reinforced concrete the construction is expensive owing to the large quantity of cement needed. The use of cement is essential mainly to protect the steel reinforcements against corrosion, it having been found that steel or iron embedded in cement mortar or cement concrete will not corrode and is preserved indefinitely as long as the cement covering is kept in tact. On the other hand steel or iron embedded in lime mortar or lime concrete will corrode probably due to the pervious nature of covering material and the penetration of moisture to the reinforcements.

The cement also has other advantages in that the adhesion between the reinforcing rods and the cement mortar or concrete is good.

Lime brickwork or lime concrete on the other hand, when properly set, has ample compressive resistance. Its resistance is not anything like as great as that of cement brickwork or concrete but is generally ample for practical purposes.

In these slabs reinforcing rods are surrounded by a relatively small quantity of cement mortar or cement concrete.

It has been found that if a small proportion of cement be added to the lime mortar or lime concrete, it not only improves the lime mortar but causes it to take its initial set much more rapidly.

For instance, if to the lime used in lime mortar or lime concrete a proportion of cement be added equal to 1/9th or so of the weight of the lime mortar, the initial set is much accelerated and the slabs in the course of a few days can have its centering struck or removed, having sufficient strength to carry its own weight successively. In the course of a few weeks the lime in the mortar also hardens and the whole structure increases in strength. The adhesive strength of the lime mortar is very greatly increased by the addition of small amount of cement. The centering of a R. B. L. B. slab is usually removed after 7 days or so.

The usual proportion of cement mortar embedding the rods is 2½ or 3 sand to 1 cement (by volume) or 1 : 2 : 3 or 1 : 2½ : 3½ or 4 cement concrete. The strength of cement mortar is dependent on the qualities of cement and sand used.

R. B. L. B. Slabs have been used on extensive scale at Renala Hydro-Electric Works, Renala Khurd, Punjab, and in many other parts of the Punjab and U. P.

Of all reinforced works, whether of brickwork or of concrete these slabs produce the cheapest roofs and floors for buildings. The plates (see Part II, pages 241-256) show the particulars of this system of roofing as actually used in 1923 at Renala Hydro-Electric Works, Renala Khurd, Punjab, and designs for roofs, and slabs on different spans upto 16 ft. In actual construction two mortar pans, one for cement mortar and the other for the lime mortar, are used by a mason. A good mason with a few days practice will easily construct 100 sq. ft. or 5 inches R. B. L. B. Slabs.

REINFORCED BRICKWORK LIME CONCRETE SLABS.

(R. B. L. C. Slabs).

(Patent).

Lime concrete is a cheaper material than brickwork in lime and much cheaper than brickwork in cement or cement concrete. In strength good lime concrete practically rivals brickwork in cement.

Crushing strength of brickwork in cement = ·19 to ·27 tons per sq. inch.

Crushing strength of ordinary concrete=·38 tons per sq. inch.*

The author also tested the crushing strengths of brickwork in cement and of lime concrete.

The strength of brickwork in cement mortar varied between 550 to 750 lbs. per sq. inch or ·25 ton to ·34 ton and the strength of lime concrete at an age of six months with common brick ballast came to 580 to 768 lbs. per sq. inch or ·26 to ·35 ton.

The strength of the lime concrete always increases with age again if a small quantity of cement be used in the lime concrete say between 5 to 10 % of the volume of concrete, the strength will be increased very considerably and such lime concrete will be as strong or stronger but cheaper than ordinary brick in cement; under such circumstances it will be decidedly cheaper to substitute the lime concrete with a slight mixture of cement for brickwork in cement or cement concrete for taking compression in slab construction. Such lime concrete can also be relied upon in all constructional works and the removal of centering or shuttering is possible within a few days from the time of construction.

Again lime corrodes steel, so no bare steel rods should be embedded in lime concrete. To avoid corrosion, steel rods should be embedded in cement mortar or cement concrete.

The cheapest construction will be to use reinforced brickwork with steel rods embedded in cement mortar or cement concrete and use lime concrete with 5 to 10 % admixture of cement on top, for taking compressive stresses developed. That will evidently produce more economical construction than reinforced brickwork or reinforced concrete.

Then comes another factor which must not be ignored in making such structures. That is shear *i.e.* shear between the lime concrete on top and reinforced brickwork or concrete below. Upto the present time reinforced concrete lime concrete slabs were not adopted in practice simply for that drawback of shear strength. That difficulty or drawback has been solved by using keys of bricks or ribs of brickwork projected into the lime concrete, thus bonding very effectively the lower brickwork or concrete with the upper lime concrete.

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*Moleswerth's po[illegible] [illegible]27-28, ed[illegible] 26.

Figures 1 to 4 in the drawing plates. Part II show illustrations where rods are embedded in lower cement concrete or cement mortar and on top lime concrete has been used and the bricks are working as keys binding the two together.

Figures 5 and 6 in the same drawing sheet show cross sections of R. B. L. C. Slabs with reinforcing rods embedded in cement mortar joists with lime concrete at top. If cross rods and top rods are required to be embedded in lime concrete they should be covered first by 2 or 3 coats of neat cement wash before use. The coats of cement varnish wash will be found also satisfactory. A rib of cement concrete or cement mortar can be used also to embed the reinforcing steel rods.

Long series of experiments on reinforced brickwork lime concrete slabs were done by the author at the Benares Hindu University Works, Benares. They were tested on various spans as 10, 12 and 20 feet.

7″ to 7½″ (5″ brick on edge+2″ to 2½″ lime concrete on top) slabs were used on 10′ and 12′ spans and 11½″ slab on 20′ span.

In all cases the slabs stood high loads, which varied between 200 to 522 lbs. per sq. ft. (external load).

TABLE FOR DESIGNING R.B.L.B. SLABS AND R.B.L.C. SLABS.

(In case of R.B.L.C. Slabs one inch extra depth is to be added to the designed depth).

Span.	Thickness of Slab.	Load in lbs. per sq. ft.	Safe stress in steel in lbs. per sq. in.	SECTIONAL AREA OF REINFORCING RODS PER FOOT WIDTH WHEN— $B=\frac{Wl^2}{8}$	$B=\frac{Wl^2}{10}$	$B=\frac{Wl^2}{12}$	Cross Reinforcements.	REMARKS.
6′	5″	112	16.000	0·099	0·079	0·066	5/16″ Rod—30″ apart.	Lime concrete or cement concrete on these slabs adds to the strengths. Load per square ft. with F_s = 20,000 lbs. per sq. ″ is 25 % more. Use $\frac{Wl^2}{8}$ for slabs with free ends. $\frac{Wl^2}{10}$ for slabs with partly fixed ends. $\frac{Wl^2}{12}$ for slabs with ends. Fixed or continuous.
7′	5″	112	16,000	0·140	·112	·091	Do do.	
8′	5″	112	16,000	0·182	·149	·121	Do do.	
9′	5″	112	16,000	0·235	·19	·57	Do dc.	
10′	6″	128	16,000	0·254	·20	·17	3/8″ Rod—30″ apart.	
11′	6″	128	16,000	0·30	·25	·204	Do do.	
12′	6″	128	16,000	..	·30	·246	Do do.	
13′	8″	140	16,000	0·38	·30	·25	Do do.	
14′	8″	140	16,000	0·45	·35	·294	Do do.	
15′	10″	160	16,000	0·45	·36	·30	Do do.	
16′	10″	160	16,000	0·51	·41	·34	Do do.	

NOTE—To avoid practical difficulty a flat brick may be used after every 3 or 4 bricks in figure 1.

Diameter.	Sec. Area.	Wt. per R. ft.	R. ft. = 1 cwt.	Diameter.	Sec. Area.	Wt. per R. ft.	R. ft. = 1 cwt.
$\frac{3}{16}$″	·02761	·094	1191	$\frac{3}{8}$″	·1104	·367	298
$\frac{1}{4}$″	·04909	·167	670·7	$\frac{7}{16}$″	·1503	·511	219
$\frac{5}{16}$″	·0767	·261	429·1	$\frac{1}{2}$″	·1963	·668	167·5

METHOD OF CONSTRUCTION.

Centering.—A centering is made as usual with a little camber at centre. (1" in 10 ft. span is ordinarily ample). The centering should be made strong enough to carry the weight of the slab with the working people.

Laying—Thoroughly wet 1st class bricks are laid in cement mortar with the bottom reinforcing rods embedded wide ribs of cement mortar or cement concrete joints, with the upper part of the joints open for bonding the upper lime concrete. If necessary, some part of the ribs may be filled up to the top at regular intervals to embed the top reinforcing rods required for negative bending moments. Lime concrete, mixed up properly in the proper proportion is laid on the brickwork both in the ribs, on the same day and the concrete is consolidated by light ramming with *thapis.* The surface is to be finished with a little cement rubbing if not specified otherwise If any other extraneous flooring is to be laid on the slab the surface should be kept rough.

If the top rods or cross rods are to be embedded in lime concrete in any part of the slab, they should be coated with 2 coats of cement varnish wash before use. The washes should be thoroughly dried up before use. Milk cement wash can be tried also.

The slab is to be thoroughly watered for 10 days and after that occasional watering should be done.

The centering of the slab should not be removed till the concrete had acquired sufficient strength to withstand the stresses developed on removal of centering. The period usually comes up to 8 or 10 days in ordinary cases.

ROOFS AND FLOORS WITH REINFORCED BRICKWORK BEAMS AND ARCHES.

(PATENT).

Jack-arched roofs and floors with reinforced brickwork beams are very durable, practically permanent.—They are probably the cheapest roofs and floors. They are cheaper and much more lasting than roofs and floors with mild steel joists and jack arches. Reinforced brickwork beams are not corroded by the archwork in lime and the lime concrete in haunches and these, on the other hand, increase very considerably the strength of the beams by increasing the depths and by taking good part of the compressive stresses developed in the structures. Mild steel reinforcements of reinforced brickwork beams, being embedded in cement mortar and cement concrete, are protected permanently from corrosion. The amount of steel required in reinforced brickwork beams is less than half the amount of steel required in mild steel joists of the same strengths ; so there is a great saving in steel in beams ; regarding brickwork of the beams that is done in cement mortar and that partly occupies the place of archwork and haunch concrete in lime ; thus the increase in cost due to brickwork of beams is very small when the cost of lime work is deducted from the same. These roofs and floors had been used with success in several buildings of the Benares Hindu University Works, Benares, in 1921-22, and in these cases in preference to reinforced brickwork slabs or jack arches with mild steel joists, on account of less cost.

With reinforcing steel rods and brickwork in cement it is quite easy to make beams on different spans of different strengths; the same sections of reinforcing rods, varying in number and length and brickwork of beams, varying in depths and widths, will make beams of varying strengths, so the question of getting different sections of joists of different lengths for different places is absent in this system.

These reinforced brickwork beams are made in situ over a temporary centering, so the problem of hoisting joists to their proper positions is also absent in this system. The life of these roofs and floors may be regarded as many centuries as there is nothing to rot.

The great point in these roofs and floors is the economy combined with stability, strength, durability and ease in construction.

METHOD OF CONSTRUCTION.

(1) A centering for the roof is prepared as done in usual cases of R. S. Joists and jack arches.

The rise of the arches is to be taken as 1½″ per ft. of span if not specified otherwise. Thus for a span of 6′, the rise of arch should be 9″.

(2) In the ribbed part R. B. Beams are made first.

(3) After that arches in lime are laid in between the beams.

(4) On the archwork lime concrete is laid in and rammed as usual.

(5) The beams and the roof are watered well for 2 weeks and after that occasional watering should be done.

(6) The centering for the arches can be removed first if desired. The centering is removed when the R. B. Beam has set well and lime concrete in haunches has partially set.

The centering for the beam should not be removed earlier than 10 days, preferably 2 weeks

In cases of R. B. Beams with "T" iron, the centering can be made on T's by propping the same in several points required. In such case the centering for the arches can be removed as usual but the props should not be removed earlier than 3 weeks after construction. The stirrups for shear should pass through holes made in the tee iron.

		cement	sand
Proportion :—For R. B. Beam work	cement mortar	1	: 2½ or 3
	cement concrete	1	: 2 or 2½
			: 3 or 3½

For lime concrete—50% mortar with—1″ G. brick ballast ¼″ to ¾″ G. chips—are to be used with cement concrete.

Lime mortar for concrete should be mixed up with 10% cement if the mortar is weak or doubtful.

Good lime mortar should have a tensile strength of 40 lbs. per sq. inch in 7 days and 80 lbs. per sq. inch in 4 weeks.

IMPROVED JACK ARCH ROOFS AND FLOORS WITH MILD STEEL BEAMS STRENGHTHENED AND PRESERVED.

(PATENT).

There is an improved method of the construction of jack arch roofs and floors with mild steel beams strengthened very considerably and preserved permanently from corrosion, thus increasing very considerably the strength and life of these structures. In usual cases the increase in strength due to strengthening is roughly equal to total depth of the structure divided by the depth of mild steel beams.

The great drawback in ordinary jack arch roofs and floors is to embed the joist or beam in brick-in-lime and lime concrete with the result that the beam is corroded by the corrosive action of the lime mortar of the brickwork and concrete. The effect of this corrosion is clearly perceived in 12 to 15 years time after construction and after 60 or 70 years time or even before that the web of the joist is eaten away very badly and it becomes like a thin sheet of perforated paper. The web swells up on account of corrosion and causes cracks in the roofs through which rain water finds its way down and accelerates the corrosion. When the roof does not crack, it is due to the fact that the whole roof acts as a monolithic slab but to rely on this action is dangerous.

According to this improved system the joist is embedded in brickwork in cement and cement concrete or in cement concrete only with the bonding of brickwork of arches with haunch concrete by means of brick keys or ribs of brickwork in cement or cement concrete with or without stirrups as necessary. The joist is kept safe against all fear of corrosion as it is a very well-known fact that iron or steel embedded in cement concrete or cement mortar remains free from rusting for ages.

In cases where the strength of the joist is desired to be increased very considerably, necessary reinforcing rods are used for the further strengthening; thus a smaller section of joist can be used on spans much bigger than that ordinarily permissible.

In cases of ordinary roofing and flooring with rolled steel joists and jack arches, the joists are usually considered as plain beams supporting the load of the roofs and floors and getting no help whatsoever about strength, from the archwork or the haunch concrete above.

In the present case the mild steel beams are encased in brickwork in cement and cement concrete and act as reinforced brickwork beams; the arch work in lime and lime concrete above being bonded or connected with the reinforced brickwork beams, all act as combined structures. The combined strength of the beams is much greater than that of the mild steel beams.

Brickwork in lime and lime concrete, when properly set, have ample compressive resistance, so in the combined structure the tensile stresses are taken mostly by the bottom flange of the joist and partly by the web and the least by the top flange; the compressive stresses are taken mostly by the lime concrete

at the top and partly by the arch work at the crown; when the lime concrete and the archwork are green and not set, most of the compressive stresses are taken by the top flange of the mild steel beam and as the lime concrete and archwork set and become hard, the compressive stresses are transferred from the top flange of the joist to them. It is for that reason that in the construction of these improved jack arch roofs and floors the joists should be kept propped at centre or at more places, as required, when the haunch concrete and archwork are green and the props are to be removed a few days after when the concrete has set hard to a certain extent.

The life of this improved type of jack arch roofing and flooring is expected to be many centuries as compared to 60 or 70 years in ordinary cases. Of course where paints are used the life of the joists are somewhat increased.

This system of construction was developed as a result of a series of experiments and researches on the subject in 1919-20 and the author hopes that it will be very economical and efficient in the construction of permanent structures which every engineer aims at.

REINFORCED BRICKWORK PITCHING.

(PATENT).

Reinforced brickwork pitching is very durable, economical in cost and very neat in appearance. It is not easily disturbed by splashes of water and is flexible to a certain extent. It is regarded as one of the ideal pitchings yet invented. 3″ (brickflat) reinforced brickwork pitching had been extensively used at the Power House Channel (carrying 2,000 cusecs with bed width of 105 ft. and depth of water 10·4′) of Sir Ganga Ram's Renala Hydro-electric Works at Renala Khurd, in Punjab. The pitching consisted of 3″ reinforced brickwork with a net-work of reinforcements ¼″ diameter rods 11″ (1 brick—10″+1″ mortar joint) apart. These pitchings were constructed from April 1924. During the last Engineering Congress in April 1924 and in the Opening Ceremony of that work in March 1925 by H. E. the Governor of the Punjab, many prominent engineers of that Province and of other places went there to see the work. The pitching is standing beautifully in all places. It is standing all the wave action of water just below the power station, where there is a 7′ fall. In many places the pitching was done on filling where puddling was done below. No soling is required below R. B. Pitching.

Drawing No. P/1A given on page 356 gives all particulars about the pitching, including its reinforcements, method of laying and analysis of cost. The average cost worked out at Renala Hydro-electric works to about -/3/- per sq. ft. and with the toe wall complete to about -/4/- per sq. ft. Again per running foot of the length of bank the cost works out to about Rs. 4. In ordinary cases of 1·1′ deep dry brick pitching with toe wall complete, the cost comes out to Rs. 6/- to Rs. 7/- per R. foot. That shows the great economy of R. B. pitching. By using thinner pitching as 2″ with bricks 10″ × 5″ × 2″ the cost can be decreased by about 20 per cent.

The general practice in many provinces specially in Punjab, Sind, U. P., Behar and Orissa and Bengal is to use dry brick pitching. In the main channels the depth of these pitchings is generally made as 13″ or 1·1′, *i. e.*, a brick-on-end over a brick flat or 3″ dry ballast. In many places the cost of these pitchings with toe wall complete, works out at Rs. 40/- per 100 sq. ft., *i. e.*, 40 per cent. more than the cost of 3″ Reinforced brickwork pitching. The reinforced brickwork pitching with a net work of steel embedded in the same is a patent construction. The amount of royalty to be paid to the Patentee as fixed by him at present is also very small. It is Rs. 2/- to Rs. 3/2/- per 100 sq. ft. (-/-/6 per sq. ft.) in usual cases according to the quantity of work.

REINFORCED SLIDING PITCHING IN FLOWING WATER.

The reinforced brickwork pitching can be adopted for sliding pitching *in running water in canals and rivers. This is one of the most important inventions in the domain of pitching.* The pitching is constructed on a made-up slope at the side of channels, canals and rivers with the top parts constructed on a temporary centering made in that inclined position in the same slope. When the pitching has set hard it is allowed to slide down until it goes to the bottom and is stopped there. The whole pitching forms a sort of sheet on the eroded bank with supports here and there. The current of water and splashed of waves working on the surface of the pitching do not affect the earth at the back. The open spaces at the back are generally silted up gradually. Holes are generally left in the pitching. This kind of pitching in flowing water will be found very useful, efficient and satisfactory. They are not like heaps of loose bricks or stones which are often thrown in large quantities to prevent scour. In cases of deep scour ribs with slabs are to be provided. The ribs will act as beams and will span bigger openings.

Dry brick pitching with cross ribs of reinforced brickwork every 8 or 10′ apart with filling inside of dry bricks is also very satisfactory, durable and cheap.

REINFORCED BRICKWORK PITCHING WITH OR WITHOUT TOE WALLS.

REINFORCED BRICKWORK PITCHING WITH RIBS OR BEAMS.

REINFORCED BRICKWORK *BOX* PITCHING.

In cases of reinforced brickwork pitching, toe wall may or may not be provided. In those cases where there are no toe walls the pitching should be anchored well by means of stout posts or pegs or anchors or by projecting bricks into the earth below at regular intervals and the bottom part of the pitching should be made flexible, so that in cases of scour at the base the pitching may take the shape of the scoured bed.

In cases of rivers and streams where unwatering the bed is a difficult problem, R. B. pitching can be made on a temporary centering above the water level (supported on a few ballahs or piles) and then sunk below. The pitching should

be made with flexible joints at regular intervals or may be made in separate pieces with simple lap according to the nature of the bed. In all cases sounding of the bed should be taken first and a section should be plotted before proceeding with pitching works.

Fig. 2 shows a section of pitching constructed on that line. The slope and a part of the bed will thus be covered by a sheet of reinforced brickwork pitching. The current of water acting on the surface of the pitching will not affect the earth at the back and the bank will thus be protected against scouring.

There are many rivers where dry beds are available at the dry season. In cases of canals dry beds are available at closure times.

In these cases toe walls at the feet of the pitching are desirable.

In cases where there is fear of scour, a short reach of flexible pitching should be connected with the toe wall by means of a hinged joint. In Fig. 4, T is the toe wall and F is the flexible pitching at the toe.

Where the pitching is made with brick-on-end or brick-on-edge reinforced it will be found very much cheaper to use cross ribs of reinforced brickwork with the filling inside of dry bricks or bats or brick-in-lime or lime concrete, or boulders of stones. Again, where depth of scour is great, or intensity of wave action is severe or the bank is precipitous, it is necessary to strengthen the pitching by means of reinforced ribs or beams at intervals.

The size and spacing of the ribs will depend upon the different circumstances to which pitchings are subjected.

Fig. 5 shows a pitching with ribs or beams down below. Cross ribs or beams are to be used where necessary.

The ribs may be at the bottom of the pitching or on the top as in Fig. 6. In the case of the beams on the top the construction is easier, but they will resist the flow of water to a certain extent. They will work also like small spurs.

Where the bank is precipitous there comes the earth pressure on the pitching. In such cases reinforced brickwork box pitching should be adopted. (See Fig. 7). It may be vertical or sloping as required.

The box pitching consists of a casing or facing of reinforced work with cross walls where necessary to bind the opposite faces with the interior part filled up with some cheaper materials as sandstones, puddle, etc., whichever available at the site of work. Thus the framework of reinforced structures with filling of a cheaper material will make a very strong massive structure which will resist easily the water action and earth pressure at the back and will not be easily shifted away by any strong current of water. By that way it is not at all a difficult thing to construct very big boxes 50 feet or 100 feet long, 6 feet to 10 feet wide, 15 feet to 30 feet high. If we consider the weight of a box 50 feet × 6 feet × 20 feet it will be over 8,000 maunds or 300 tons nearly. A series of boxes like these will protect any bank. No current of water however strong can shift these boxes easily. There are vast possibilities of bank protections with this sort of box pitching. The casing may be made of R. B. or R. B. C. work. If necessary the surface may be covered with cement plaster or rubbing along with the construction especially where there is fear of wear and tear or saltpetre action on bricks.

REINFORCED CONCRETE

BY

S. L. Bhatia, B.Sc., C. E.

POINTS FOR R. C. USERS.

1. Cement.—
   (a) Use the best cement obtainable of well known brand.
   (b) Use slow setting cement.
   (c) Test thoroughly before using. Should comply with all the requirements of British Standard specification.
   (d) Test each consignment frequently for soundness time of setting and fineness of grinding.
   (e) Residue should not be more than 10% on 180 mesh sieve and not more than 1% on 76 mesh sieve.
   (f) Specific gravity not less than 3·1.
   (g) Briquettes one sq. inch in section should stand not less than the following stresses.
   Neat cement after 7 days 600 lbs. per sq. inch.
   1 cement and 3 sand after 7 days 325 lbs. per sq. inch.
2. Sand.—
   (a) The sand should be clean and gritty.
   (b) Do not use sand which leaves a yellow or black residue on the hand when examined.
3. Aggregate.—
   (a) Select the aggregate carefully, keep a sample of the selected aggregate and compare with it each consignment.
   (b) If possible select an aggregate that does not require washing.
   (c) Do not use a dirty aggregate.
   (d) Crush all aggregate to pass a $\frac{3}{4}''$ mesh.
   (e) Screen out all material less than $\frac{1}{4}''$ and call it sand.
   (f) The best materials are granite, stone, gravel, brick and burnt ballast.
   (g) Coke breeze, pan breeze or boiler ashes ought not to be used.
   (h) Allowance for the smaller resistance of these materials must be made in the design where they are used.
4. Concrete Proportioning.—
   (a) Usual proportions: For reinforced work where very good concrete is required the proportion are 1 : 2 : 4. For medium quality concrete such as used in foundations, walls, arches, ordinary floors and stairs the proportions should be 1 : 2½ : 5. For heavy retaining walls, piers and abutments which are subject to considerable strain use 1 : 3 : 6 where concrete is employed in large masses and is subjected to simple compression of small intensity a still poorer concrete, *i.e.*, 1 : 4 : 8 will do.
   (b) Measure the voids in aggregate and sand before deciding the proportions for concrete.
5. Steel.
   (a) Before use in work the metal should be clean and free from scale or loose rust.
   (b) It should not be oiled or painted but a thick wash of cement grout is desirable.

(c) Bending test: The test piece should withstand without fracture being doubled over, until the internal radius is not greater than $1\frac{1}{2}$ times the thickness of test piece and the sides are parallel.

(d) End welding shall not be allowed.

(e) All bending of bars should be done cold.

(f) The end of all bars should be bent over to form hooks in order to prevent slipping.

(g) The reinforcement should preferably of small diam. A greater number of thin rods will be better than smaller number of thick rods.

6. Mixing.—

(a) Mix the sand and cement well together dry.

(b) Add water from a rose.

(c) Do not use sea water.

(d) Damp the aggregate, add it to the mixed sand and cement and mix all together until the colour is uniform.

7. Laying.—

(a) Lay quickly in small quantities.

(b) Give special attention to ramming.

(c) See that the concrete is well rammed round all the rods and thoroughly consolidated.

(d) Do not let dirt from trenches get into the concrete.

(e) See that the reinforcements are not removed by ramming.

(f) When joining on to work which has set, hack the surface and put on $\frac{1}{2}''$ layer of cement and sand mortar.

(g) Protect against frost and hot sunshine.

8. Centering.—

(a) The centering must be of such dimensions and so constructed as to remain (1) rigid, (2) simple in construction, (3) easily erected and removed, (4) so constructed that the surfaces shall not deform the concrete by reason of the expansion due to moisture, (5) so designed if possible that they may be reused in various portions of the work, (6) so prepared that the concrete will not become attached to the surfaces, (7) carefully cleaned and lime washed before use.

(b) Allow camber for long span beams.

(c) Damp the centering before laying concrete.

(d) Do not remove until concrete is properly set.

(e) All joints should be fairly tight.

9. Striking of Centres —

The time during which the centres should remain in position depends upon varying circumstances. The casing of columns, sides of beams and soffits of floor slabs should remain up for at least 14 days. Soffit of beam and large span arches should remain up for at least 28 days.

10. Acceptance Test.—

(a) Should never be so severe as to endanger the structure tested. The testing load shall not exceed the load for which the structure has been designed.

(b) No test loading should be attempted until the structure has been completed for 3 months.

(c) Max. test load may be $1\frac{1}{2}$ times the load for which the structure has been designed.

DATA FOR FLOOR AND ROOF LOADS.

The dead load consists of actual weights of walls, floors, roofs, etc. The superimposed load shall consist of all loads other than the dead load.

For the purpose of calculating the loads on foundations, pillars, piers, walls, beams, etc., the superimposed load on each floor and on the roof shall be estimated as equivalent of the following dead loads:—

Ordinary living rooms	80 lbs. per sq. ft.
Offices and School rooms	112 do.
Officers quarters	90 do.
Public halls, theatres, etc.	160 do.
Meeting rooms	112 do.
Ball room and floors subject to vibration	168 do.
Museums, stores and warehouses ..	224 do.
Workshops carrying light machinery ..	168 do.
Workshops carrying heavy machinery ..	200 to 400 do.
Weight of men in crowds packed closely ..	140 lbs. do.
,, ,, ,, ,, ,, ordinary ..	80 lbs. do.

For the purpose of calculating the total load to be carried on foundations, pillars and walls of buildings of more than two stories in height, the load for the roof and top-most storey shall be calculated in full, but for the lower stories a reduction of the superimposed load shall be allowed as follows:—

For the next floor below the top floor 10% less, for the next storey 20% and so on, to the floor at which the reduction amounts to 50%. For all other floors below take 50%.

In the case of ware-houses and buildings containing heavy machinery, it is desirable not to make any reduction.

WEIGHTS.

In calculating the safe load on beams and floor slabs allowance shall be made for the weight of the beams or floor slab itself.

The weight of reinforced concrete may be taken 150 lbs. per cubic ft.

USUAL WORKING STRESSES PROPORTION 1 : 2 : 4.

Concrete in compression in beam subject to bending ..	600 lbs. per sq. inch.
Concrete in column under simple compression ..	500 lbs. do.
Concrete in shear in beam	60 lbs. do.
Adhesion of concrete to steel	100 lbs. do.
Steel in tension	16,000 lbs. do.
Steel in compression	15 times the stress in concrete.
Steel in shear	12,000 lbs. per sq. inch.

Provision shall be made for the stresses due to eccentric loading, neither the steel nor the concrete shall be subjected to combined stresses which together exceed the maximum permissible direct stress.

BENDING MOMENTS.

Always consider the effective span for calculating Bending moments (1) Bending moment at the centre of a beam supported at both ends and having a uniformly distributed load $= \frac{WL}{8}$. (2) Bending moment at the centre of a beam supported at both ends and having a concentrated load in the middle $= \frac{WL}{4}$.

(3) Bending moment at the fixed end of a cantilever with a single concentrated load at the free end = WL. (4) Bending moment at the fixed end of a cantilever with a load uniformly distributed $= \frac{WL}{2}$. (5) Bending moment at the supports and at the centre of a beam with both ends fixed and a single concentrated load at centre $= \frac{WL}{8}$. (6) Bending moment at the fixed end of a beam with one end fixed and one end supported and the load uniformly distributed $= \frac{WL}{8}$. (9) Bending moment at the centre of a beam with both ends fixed and the loads uniformly distributed $= \frac{WL}{12}$. (10) Bending moment across the centre of a square slab supported on 4 edges and reinforced in two directions at right angles to each other with load uniformly distributed $= \frac{WL}{8} \times \cdot 4 = \frac{WL}{20}$.

Notations for calculations used in Reinforced concrete :—

a = Arm of the resisting moment or lever arm (inches).

A_t = total area of steel bars in square inches.

B or B.M = Bending moment = moment of resistance.

b = breadth of rectangular beam in inches or the breadth of a flange of a T. beam in inches.

b_r = width of rib in T. beams in inches.

b_s = effective breadth of slab in T. beam in inches.

c = Maximum stress in concrete compressive edge in lbs. per sq. inch.

d = effective depth from the top to the centre of steel bars in inches.

d_s = total depth of slab in T. beams in inches.

E_c = Elastic modulus for concrete = 2,000,000 lbs. per sq. inch.

E_s = Elastic modulus for steel = 30,000,000 lbs. per sq. inch.

I. = moment of inertia.

K = Ratio of depth to neutral axis from compressive edge to effective depth $= \frac{n}{d}$

M = Moment of Resistance $= 95bd^2$.

$m = \frac{E_s}{E_c}$ modular ratio = 15.

n_1 = ratio of lever arm and effective depth $= a/d$.

n = depth to neutral axis from the compressive edge in inches.

O = Perimeter of the reinforcing rods at any section.

r = percentage of steel reinforcement $= 100 \cdot \frac{At}{b\,d} = \cdot 675$ (when c and t have values of 600 lbs. per sq. in. and 16,000 lbs. per sq. inch.)

t = stress in steel taken as uniform in lbs. per sq. inch.

W = total load carried by the beam.
Y = the distance between neutral axis and centre of steel.
Z = distance between the compression edge and the line of resultant compression in a tee-beam.

The following formulæ hold good for the design of slabs and rectangular beams :—

$$n = \frac{15\,c}{t+15c}\,d \quad \ldots\ldots\ldots \quad (1)$$

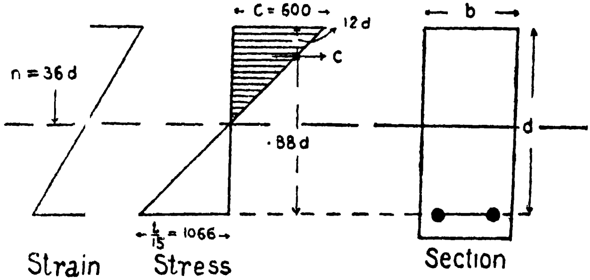
$= \cdot36\,d$ (where t 16,000 lbs. per sq. inch and c 600 lbs. per sq. inch)

$$M = \tfrac{1}{2}\,c\,n\,b\,(d-\frac{n}{3}). \quad \ldots\ldots \quad (2)$$

$=95\,b\,d^2$ (where c = 600 lbs per sq. inch

$$\cdot0294\,\sqrt{B\cdot M} \quad \ldots\ldots\ldots \quad (3)$$

$$\tfrac{1}{2}\,c\,n\,b = tA_t \quad (4)$$



EXAMPLE.—Design a freely supported reinforced concrete slab. Span 8 ft. Live load 112 lbs. per sq. ft.
Assume a slab 5 inches thick.

Load. { Weight of slab $= \frac{5}{12} \times 150$ = 63 lbs. per sq. ft.
Live load................. = 112 lbs. per sq. ft.

Total load. 175 lbs. per sq. ft.

Bending moment $= \frac{WL}{8} = \frac{(175 \times 8) \times 8 \times 12}{8} = 16{,}800$ inch lbs.

$d = \cdot0294\,\sqrt{B.M} = \cdot0294\,\sqrt{16{,}800} = 4''$

Allowing 1 inch of covering, the total depth of slab = 4+1 = 5 inches.

$tA_t = \tfrac{1}{2}\,c\,n\,b.$

$$A_t = \tfrac{1}{2} \times \frac{c \times n \times b}{t} = \tfrac{1}{2} \times \frac{600 \times (\cdot36 \times 4) \times 12}{16000}$$

$= \cdot324$ sq. inches per foot width of slab.

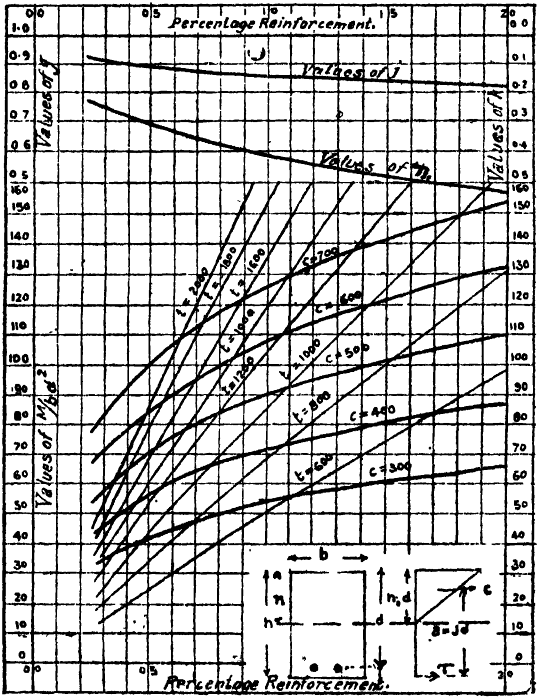
$\tfrac{5}{8}''$ rods at 12 inches centres will do.

In addition to the main bars in slabs some rods in the other direction are very desirable. The object of this is as follows:—

When concrete sets and dries, it contracts in all directions. Therefore a floor slab resting on the walls of a building which resist contraction tends to produce cracks, and if reinforced in one direction only, cracks badly in that direction owing to the absence of tensile strength at right angles. The spacing of cross bars may be about 4 times the spacing of main bars.

About ½" covering (minimum) should be provided in order to protect the slabs or beams reinforcement from corrosion. This cover is best obtained by laying the bars on wooden slats of the required thickness about 4 ft. apart and withdrawing these gradually, as concreting proceeds and rods are at home in the concrete.

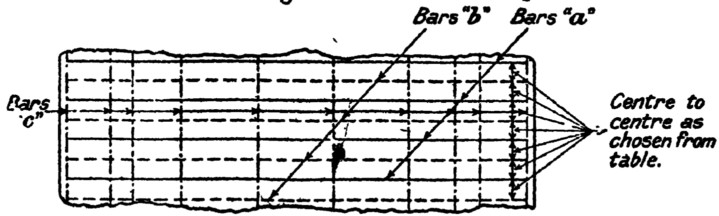
DIAGRAM FOR RECTANGULAR BEAMS AND SLABS
T BEAMS WHERE NEUTRAL AXIS IS WITHIN SLAB



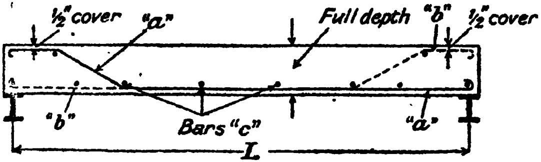
ENDS FREE

BENDING MOMENT = $\frac{W \cdot L}{8}$

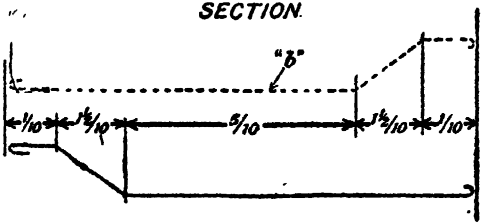
STRESSES:- Steel, 16,000 lbs per in.² Concrete, 600 " " "



PLAN



SECTION



APPROX BAR BENDING

N.B.
For distributing bars "c" ¼ ROUNDS of convenient lengths at right angles to and on top of Main Reinforcing bars at the following centres.

SLAB.	d c
3'5"	18"
4'0"	18"
4'5"	16"
5'0"	14"
5'5"	13"
6'0"	12"
6'5"	11"
7'0"	10"
7'5"	9"
8'0"	8'5"
8'5"	8'0"
9'0"	7'5"
9'5"	7'0"
10'0"	6'5"

DESIGN OF T. BEAMS.

*Reinforced concrete floors usually consist of reinforced slabs with reinforced beams at definite intervals. The whole being monolithic. In designing T. beams the following factors have to be considered :—

(1) The total depth of slab d_s

(2) The effective breadth of the slab b_s

(3) The effective depth of the beam

(4) The reinforcement required

In calculations the effective breadth b_s of slab is taken as :—

(1) $\frac{3}{4}$th the distance between beams.

(2) $\frac{1}{3}$rd the span.

(3) 15 times the slab thickness.

(4) 6 times the width of the rib of the T. beam ; whichever is less.

The width of the rib b_r should not be less than—

(1) $\frac{1}{6}$th the width b_s

(2) $\frac{1}{3}$rd of the depth.

Two cases of T. beams—

1. Neutral axix lies within slab.

This is dealt with according to the rectangular beams and substituting b_s (breadth of slab) for b in the formulæ for rectangular beams. Where neutral axis coincides with the lower edge of slab $n = d_s$

2. Neutral axis within the rib :—

The following formulæ hold good in designing T. beam :—

$$\frac{c}{2n}\left\{b_s\, n^2 - (b_s - b_r)\, y_1^{\,2}\right\} = t.\ A_t \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{c}{3n}\left\{b_s\, n^3 - (b_s - b_r)\, y_1^{\,3}\right\} + t\, A_c\, (d - n) \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$t = m\, c\, \frac{d - n}{n} \quad \ldots\ldots\ldots\ldots \quad (3)$$

*For Figure see page 338.

TABLE (1)

Values of d, n, and A_t for a width of slab or beam of 12 inches for various values of t and c, B being the bending moment.

Allowable maximum stress in lbs. per sq. in. Steel.	Concr.	Effective depth in inches d.	Distance of neutral axis in inches n	*Sectional area of steel for 12" strip in square inches:* A_t.	A_t.
14000	500	$\cdot032\sqrt{B}$	$\cdot350d$	$\cdot0753\,d$	$\cdot00241\sqrt{B}$
		$\cdot114\sqrt{\frac{B}{b_s}}$			$\cdot000695\sqrt{B\,b_s}$
14000	600	$\cdot028\sqrt{B}$	$\cdot391d$	$\cdot10036\,d$	$\cdot002810\sqrt{B}$
		$\cdot099\sqrt{\frac{B}{b_s}}$			$\cdot000811\sqrt{B\,b_s}$
15000	400	$\cdot0390\sqrt{B}$	$\cdot286d$	$\cdot04577\,d$	$\cdot001785\sqrt{B}$
		$.1380\sqrt{\frac{B}{b_s}}$			$\cdot000515\sqrt{B\,b_s}$
15000	500	$\cdot0335\sqrt{B}$	$\cdot333d$	$\cdot06660\,d$	$\cdot00226\sqrt{B}$
		$\cdot1160\sqrt{\frac{B}{b_s}}$			$\cdot00064\sqrt{B\,b_s}$
15000	600	$\cdot029\sqrt{B}$	$\cdot375d$	$\cdot08892\,d$	$\cdot002624\sqrt{B}$
		$\cdot101\sqrt{\frac{B}{b_s}}$			$\cdot000756\sqrt{B\,b_s}$
16000	400	$\cdot042\sqrt{B}$	$\cdot273d$	$\cdot04092\,d$	$\cdot00049\sqrt{B}$
		$\cdot1450\sqrt{\frac{B}{b_s}}$			$\cdot001719\sqrt{B\,b_s}$
16000	500	$\cdot0340\sqrt{B}$	$\cdot319d$	$\cdot05964\,d$	$\cdot000590\sqrt{B}$
		$\cdot1180\sqrt{\frac{B}{b_s}}$			$\cdot002030\sqrt{B\,b_s}$
16000	600	$\cdot0294\sqrt{B}$	$\cdot36\,d$	$\cdot0810\,d$	$\cdot002381\sqrt{B\,b_s}$
		$\cdot1020\sqrt{\frac{B}{b_s}}$			$\cdot000688\sqrt{B}$

N.B.—The upper values are for calculating slabs and the lower ones for calculating T beams.

SHEARING RESISTANCE OF CONCRETE BEAMS.

If a beam is designed to resist tension and compression at the bottom and top, it may fail due to shear resistance. The best method of resisting shear to prevent failure is by means of providing stirrups or some of the tension rods may be bent up at 45°.

The shear is given by the following formula—

S = area of section × safe tensile stress.

With concrete we generally assume 60 lbs. per sq. inch as the safe tensile stress, ∴ shear stress = 60 × area of beam in square inches.

EXAMPLE.—A beam 10 inches deep, 8 inches effective depth, 6 inches wide is designed to resist bending. What is the safe load it will carry without failure by shear and without shear reinforcement.

The depth reckoned in shear = d— $\cdot 88d = \cdot 88 \times 8 = 7\cdot 04$

b = 6 inch

t = 60 lbs. per sq. inch ∴ shear $= 7\cdot 04 \times 6 \times 60$

$= 2534\cdot 4$ lbs.

Safe load $= 2 \times 2534\cdot 4 = 5069$ lbs.

Slabs do not ordinarily require any shear reinforcement not as a rule singly reinforced rectangular beams, though it is usual always to turn half the tensile reinforcement in all beams at a distance not exceeding ¼ from the supports. T. beams and all doubly reinforced beams must always be tested for shear.

If S. exceeds 60 lbs. per sq. inch web reinforcement must be given.

If S. exceeds 120 lbs. per sq. inch ; b and b_r should be increased.

SIMPLY SUPPORTED BEAMS.

B.M. $= \frac{WL}{8}$; t = 16000 lbs. per sq. inch ; c = 600 lbs. per sq. inch.

Table (2)—Load = 40 lbs. per sq. ft.

Span in ft.	B.M. inch. lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of bars.
5	1500	38·8	1·15	3	·094	¼″ at 6″ centres.
6	2160	46·4	1·25	3	·101	¼″ „ 5½″ „
7	2940	54·2	1·50	3	·112	¼″ „ 5″ „
8	3840	62·0	1·82	3	·147	¼″ „ 4″ „
9	4360	66·0	2·10	3·0	·170	¼″ „ 3½″ „
10	6000	77·8	2·28	3·5	·184	¼″ „ 3″ „
11	7260	85·2	2·50	3·5	·202	¼″ „ 3″ „
12	8640	93·0	2·75	4·0	·222	⅜″ „ 6″ „
13	10140	100·8	2·95	4·0	·240	⅜″ „ 5½″ „
14	11760	108·4	3·19	4·5	·258	⅜″ „ 5″ „
15	13500	116·2	3·45	4·5	·279	⅜″ „ 4½″ „
16	15360	124·0	3·68	5·0	·295	⅜″ „ 4″ „
17	16840	129·8	3·80	5·0	·307	⅜″ „ 4″ „
18	19440	139·4	4·15	5·5	·336	½″ „ 7″ „
19	21660	147·2	4·35	5·5	·352	½″ „ 6½″ „
20	24000	155·0	4·55	6·0	·368	½″ „ 6″ „
22	29040	170·6	5·00	6·0	·405	½″ „ 5½″ „
24	34560	185·8	5·40	6·5	·437	½″ „ 5″ „

B.M. : W.L. ; t = 16,000 lbs. per sq. inch ; c=600 lbs. per sq. inch.

Table (3)—Load = 80 lbs per sq. ft.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches	Diameter and spacing of bars.
5	3000	54·7	1·6	3·0	·129	¼″ at 4½″ centres
6	4320	65·7	2·03	3·5	·164	¼″ ,, 3½″ ,,
7	5880	76·7	2·25	3·5	·182	⅜″ ,, 7″ ,,
8	7680	87·6	2·57	4·0	·207	⅜″ ,, 6″ ,,
9	8720	98·6	2·90	4·5	·235	⅜″ ,, 5½″ ,,
10	12000	109·5	3·21	4·5	·260	⅜″ ,, 5″ ,,
11	14520	120·5	3·54	5·0	·286	⅜″ ,, 4½″ ,,
12	17280	131·4	3·86	5·0	·312	⅜″ ,, 4″ ,,
13	20880	142·4	4·18	5·5	·338	½″ ,, 6½″ ,,
14	23520	153·3	4·50	5·5	·364	½″ ,, 6½″ ,,
15	27000	164·3	4·83	6·0	·391	½″ ,, 6″ ,,
16	30720	175·3	5·00	6·0	·405	½″ ,, 5½″ ,,
17	33680	186·2	5·47	6·5	·443	½″ ,, 5″ ,,
18	38880	197·2	5·80	7·0	·469	½″ ,, 5″ ,,
19	43320	208·1	6·10	7·5	·494	½″ ,, 4½″ ,,
20	48000	219·1	6·44	7·5	·521	½″ ,, 4½″ ,,
22	58080	241·0	7·08	8·0	·573	½″ ,, 4″ ,,
24	69120	263·0	7·75	9·0	·627	½″ ,, 3½″ ,,

t = 16000 lbs. per sq. inch ; c=600 lbs.

Table (4)—Load=100 lbs. per sq. ft.

Span in ft.	B. M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches	Diameter and spacing of bars.
5	3750	61·5	1·80	3·0	·147	¼″ at 4″ centres.
6	5400	74·0	2·17	3·5	·175	⅜″ ,, 7″ ,,
7	7350	86·0	2·52	4·0	·204	⅜″ ,, 6½″ ,,
8	9600	98·5	2·90	4·0	·234	⅜″ ,, 5½″ ,,
9	12150	106·8	3·13	4·5	·253	⅜″ ,, 5″ ,,
10	15000	114·5	3·36	5·0	·272	⅜″ ,, 4½ ,,
11	18150	134·8	3·96	5·0	·320	½″ ,, 7″ ,,
12	21600	147·0	4·32	5·5	·349	½″ ,, 6½″ ,,
13	23350	159·0	4·67	6·0	·378	½″ ,, 6″ ,,
14	29400	171·8	5·05	6·5	·409	½″ ,, 5½″ ,,
15	33750	183·6	5·39	6·5	·436	½″ ,, 5″ ,,
16	38400	196·0	5·76	7·0	·466	½″ ,, 5″ ,,
17	43350	208·2	6·12	7·5	·496	½″ ,, 4½″ ,,
18	48600	220·5	6·48	7·5	·525	½″ ,, 4″ ,,
19	54150	232·8	6·84	8·0	·554	½″ ,, 4″ ,,
20	60000	245·0	7·20	8·5	583	½″ ,, 4″ ,,
22	72600	269·5	7·96	9·0	·644	½″ ,, 3½ ,,
24	86400	294·0	8·64	10·0	·670	⅝″ ,, 5½ ,,

$B.M. = \frac{W.L.}{8}$; t = 16,000 lbs. per sq. inch; c = 600 lbs. per sq. inch.

Table (5)—Load = 112 lbs. per sq. ft.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inch.	Diameter and spacing of bars.
5	4200	65·0	1·91	3·0	·154	¼" at 3½" centres.
6	6048	78·0	2·29	3·5	·185	⅜" ,, 7" ,,
7	8332	91·0	2·67	4·0	·216	⅜" ,, 6" ,,
8	10752	103·5	3·04	4·5	·246	⅜" ,, 5" ,,
9	13608	117·0	3·43	4·5	·279	⅜" ,, 4½" ,,
10	16800	129·5	3·80	5·0	·307	⅜" ,, 4" ,,
11	20328	142·	4·18	5·5	·338	½" ,, 6½" ,,
12	24192	155·4	4·56	6·0	·370	½" ,, 6" ,,
13	28392	168·4	4·95	6·0	·400	½" ,, 5½" ,,
14	32928	181·5	5·33	6·5	·431	½" ,, 5" ,,
15	37800	194·5	5·71	7·0	·462	½" ,, 5" ,,
16	43008	207·5	6·10	7·5	·494	½" ,, 4½" ,,
17	48552	220·4	6·47	7·5	·524	½" ,, 4½" ,,
18	54432	233·3	6·85	8·0	·554	½" ,, 4" ,,
19	60648	246·0	7·23	8·5	·585	½" ,, 4" ,,
20	67200	259·4	7·62	9·0	·616	⅝" ,, 5½" ,,
22	81312	285·2	8·38	9·5	·678	⅝" ,, 5" ,,
24	96768	311·0	9·14	10·5	·740	⅝" ,, 4½" ,,

$$B.\,M. = \frac{WL}{8}\,;\; t = 16{,}000 \text{ lbs. per sq. inch}\,;\; c = 600 \text{ lbs. per sq. inch.}$$

Table (6)—Load = 120 lbs. per sq. foot.

Span in ft.	B. M. inch lbs.	$\sqrt{B.\,M.}$	*d* inches.	*h* inches.	A_t sq. inches.	Diam. and spacing of bars.
5	4500	67·2	1·97	3·0	·159	¼″ at 3½″ centres.
6	6480	80·0	2·35	3·5	191	⅜″ „ 7″ „
7	8820	94·0	2·76	4·0	·221	⅜″ „ 6″ „
8	11520	107·5	3·16	4·5	·225	⅜″ „ 5″ „
9	14580	120·5	3·54	5·0	·286	⅜″ „ 4½″ „
10	18000	134·2	3·94	5·0	·319	⅜″ „ 4″ „
11	21780	147·3	4·43	5·5	·358	½″ „ 6½″ „
12	25920	161·0	4·74	6·0	·384	½″ „ 6″ „
13	30420	174·5	5·13	6·5	·415	½″ „ 5½″ „
14	35280	187·8	5·52	7·0	·447	½″ „ 5″ „
15	40500	201·2	5·91	7·0	·477	½″ „ 4½″ „
16	46500	214·2	6·29	7·5	·509	½″ „ 4½″ „
17	52020	228·0	6·70	8·0	·542	½″ „ 4″ „
18	58320	241·6	7·30	8·5	·591	½″ „ 3½″ „
19	64980	255·0	7·49	8·5	·606	⅝″ „ 6″ „
20	72000	268·4	7·89	9·0	·636	⅝″ „ 5½″ „
22	87120	295·0	8·67	9·5	·701	⅝″ „ 5″ „
24	103680	322·0	9·46	10·5	·766	⅝″ „ 4½″ „

$$B.\,M. = \frac{WL.}{8};\ t = 16{,}000 \text{ lbs. per sq. inch};\ c = 600 \text{ lbs. per sq. inch.}$$

Table (7)—Load = 150 lbs. per sq. foot.

Span in ft.	B. M. inch lbs.	$\sqrt{B.\,M.}$	d inches.	h inches.	A_t sq. inchs.	Diam. and spacing. of bars.
5	5625	75·0	2·20	3·5	·178	⅜″ at 7″ centres.
6	8100	90·0	2·64	4·0	·213	⅜″ ,, 6″ ,,
7	11025	105·0	3·08	4·5	·249	⅜″ ,, 5″ ,,
8	14400	120·0	3·52	5·0	·284	⅜″ ,, 4½″ ,,
9	18225	135·0	3·83	5·0	·309	⅜″ ,, 4″ ,,
10	22500	150·0	4·41	5·5	·357	½″ ,, 6½″ ,,
11	27225	165·0	4·85	6·0	·392	½″ ,, 6″ ,,
12	32400	180·0	5·29	6·5	·428	½″ ,, 5½″ ,,
13	38025	195·0	5·73	7·0	·464	½″ ,, 5″ ,,
14	44100	210·0	6·17	7·5	·499	½″ ,, 4½″ ,,
15	50625	225·0	6·61	8·0	·535	½″ ,, 4″ ,,
16	57600	240·0	7·05	8·5	·571	½″ ,, 4″ ,,
17	65025	255·0	7·36	9·0	·615	⅝″ ,, 6″ ,,
18	72900	270·0	7·93	9·0	·642	⅝″ ,, 5½″ ,,
19	81225	285·0	8·24	9·5	667	⅝″ ,, 5½″ ,,
20	90000	300·0	8·82	10·0	·713	⅝″ ,, 5″ ,,
22	108900	330·0	9·70	11·0	·785	⅝″ ,, 4½″ ,,
24	129600	336·0	10·68	12·0	·864	⅝″ ,, 4″ ,,

$B.M. = \frac{W.L}{8}$; t = 16,000 lbs. per sq. inch ; c = 600 lbs. per sq. inch.

Table (8)—Load = 160 lbs. per sq. ft.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inch.	Diam. and spacing of bars.
5	6000	77·9	2·29	3·5	·185	⅜″ at 7″ centres..
6	8640	93·0	2·73	4·0	·221	⅜″ ,, 6″ ,,
7	11760	108·5	3·18	4·5	·257	⅜ ,, 5″ ,,
8	15360	124·0	3·64	5·0	·294	⅜″ ,, 4½″ ,,
9	19440	139·0	4·09	5·5	·331	⅜″ ,, 4″ ,,
10	24000	155·0	4·55	6·0	·368	½″ ,, 6″ ,,
11	29040	170·3	5·00	6·0	·405	½″ ,, 5½″ ,,
12	34560	186·0	5·40	6·5	·437	½″ ,, 5″ ,,
13	40560	201·3	5·91	7·0	·477	½″ ,, 4½″ ,,
14	47040	217·0	6·37	7·5	·515	½″ ,, 4½″ ,,
15	54000	232·4	6·83	8·0	·552	½″ ,, 4″ ,,
16	61440	247·8	7·28	8·5	·589	½″ ,, 4″ ,,
17	69360	263·4	7·74	9·0	·626	⅝″ ,, 5½″ ,,
18	77760	278·8	8·19	9·5	·663	⅝″ ,, 5½″ ,,
19	86640	294·3	8·65	10·0	·700	⅝″ ,, 5″ ,,
20	96000	310·0	9·11	11·0	·737	⅝″ ,, 4½″ ,,
22	116160	340·8	10·01	12·0	·810	⅝″ ,, 4½″ ,,
24	138240	371·8	10·93	13·0	·884	⅝″ ,, 4″ ,,

B. M. $=\frac{W.L.}{8}$; t =16,000 lbs. per sq. inch ; c = 600 lbs. per sq. inch.

Table (9)—Load = 168 lbs. per sq. foot.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	At sq. inches.	Diam. and spacing of of Reinforcement.
5	6300	79·3	2·33	3·5	·188	$\frac{3}{8}''$ at 7″ centres.
6	9072	95·2	2·79	4·0	·225	$\frac{3}{8}''$ „ $5\frac{1}{2}''$ „
7	12348	111·3	3·27	4·5	·264	$\frac{3}{8}''$ „ 5″ „
8	16128	127·0	3·73	5·0	·302	$\frac{3}{8}''$ „ $4\frac{1}{2}''$ „
9	20412	146·3	4·29	5·5	·347	$\frac{3}{8}''$ „ 4″ „
10	25200	158·8	4·65	6·0	·376	$\frac{1}{2}''$ „ 6″ „
11	30492	174 6	5·13	6·5	·415	$\frac{1}{2}''$ „ $5\frac{1}{2}''$ „
12	36288	190·7	5·59	7·0	·452	$\frac{1}{2}''$ „ 5″ „
13	42588	206·3	6·05	7·5	·490	$\frac{1}{2}''$ „ $4\frac{1}{2}''$ „
14	49392	222·2	6·53	8·0	·528	$\frac{1}{2}''$ „ 4″ „
15	56700	238·1	6·99	8·0	·566	$\frac{1}{2}''$ „ 4″ „
16	64512	254·0	7·46	8·5	·603	$\frac{5}{8}''$ „ 6″ „
17	72828	269·8	7·91	9·0	·640	$\frac{5}{8}''$ „ $5\frac{1}{2}''$ „
18	81648	285·8	8·40	9·5	·680	$\frac{5}{8}''$ „ 5″ „
19	90972	301·3	8·85	10·0	·716	$\frac{5}{8}''$ „ 5″ „
20	100800	317·6	9·33	11·0	·755	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
22	121968	349·1	10·26	12·0	·830	$\frac{5}{8}''$ „ 4″ „
24	145152	381 0	11·20	13·0	·907	$\frac{3}{4}''$ „ $5\frac{1}{2}''$ „

$B.M. = \frac{W.L.}{8}$; t = 16,000 lbs. per sq. inch ; c = 600 lbs. per sq. inch.

Table (10)—Load = 200 lbs. per sq. ft.

Span. in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam and spacing of bars.
5	7500	87·0	2·55	4·0	·202	$\frac{3}{8}''$ at $6\frac{1}{2}''$ centres.
6	108800	104·0	3·05	4·5	·247	$\frac{3}{8}''$,, $5''$,,
7	14700	121·0	3·55	5·0	·287	$\frac{3}{8}''$,, $4\frac{1}{2}''$,,
8	19200	138·8	4·08	5·5	·330	$\frac{3}{8}''$,, $4''$,,
9	24300	156·0	4·55	6·0	·368	$\frac{1}{2}''$,, $6''$,,
10	30000	173·0	5·08	6·5	·411	$\frac{1}{2}''$,, $5\frac{1}{2}''$,,
11	36300	190·8	5·60	7·0	·453	$\frac{1}{2}''$,, $5''$,,
12	43200	208·0	6·11	7·5	·495	$\frac{1}{2}''$,, $4\frac{1}{2}''$,,
13	50700	225·0	6·61	8·0	·535	$\frac{1}{2}''$,, $4''$,,
14	58800	242·6	7·13	8·5	·577	$\frac{1}{2}''$,, $4''$,,
15	67500	260·0	7·64	9·0	·618	$\frac{5}{8}''$,, $5\frac{1}{2}''$,,
16	76800	277·0	8·14	9·5	·659	$\frac{5}{8}''$,, $5\frac{1}{2}''$,,
17	86700	294·6	8·46	10·0	·685	$\frac{5}{8}''$,, $5''$,,
18	97200	311·8	9·16	10·5	·742	$\frac{5}{8}''$,, $4\frac{1}{2}''$,,
19	108300	329·2	9·65	11·0	·781	$\frac{3}{4}''$,, $6\frac{1}{2}''$,,
20	120000	346·5	10·17	11·5	·823	$\frac{3}{4}''$,, $6''$,,
22	145200	381·0	11·20	12·5	·907	$\frac{3}{4}''$,, $5\frac{1}{2}''$,,
24	172800	415·8	12·22	14·0	·989	$\frac{3}{4}''$,, $5''$,,

B. M $= \frac{W.L.}{8}$; $t =$ 16,000 lbs. per sq. inch.; c = 600 lbs. per sq. inch.
Table (11)—Load = 224 lbs. per sq. foot.

Span in ft.	B. M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of bars.
5	8397	91·4	2·68	4·0	·217	3/8″ at 6″ centres.
6	12096	109·9	3·23	4·5	·261	3/8″ " 5″ "
7	16464	128·3	3·77	5·0	·305	3/8″ " 4″ "
8	21504	146·6	4·41	5·0	·357	3/8″ " 3½″ "
9	27216	165·0	4·85	6·0	·392	½″ " 6″ "
10	33600	183·2	5·38	6·5	·435	½″ " 5″ "
11	40656	201·7	5·93	7·0	·480	½″ " 4½″ "
12	48384	219·8	6·46	7·5	·523	½″ " 4½″ "
13	58784	242·4	7·12	8·5	·576	½″ " 4″ "
14	65856	256·6	7·54	9·0	·610	5/8″ " 6″ "
15	75600	274·8	8·07	9·5	·653	5/8″ " 5½″ "
16	86016	293·8	8·62	10·0	·708	5/8″ " 5″ "
17	97104	311·6	9·15	10·5	·741	5/8″ " 4½″ "
18	108864	329·8	9·69	11·5	·784	5/8″ " 4½″ "
19	121296	348·2	10·22	12·0	·817	5/8″ " 4½″ "
20	134400	366·7	10·78	12·5	·873	¾″ " 6″ "
22	162624	403·2	11·84	13·5	·958	¾″ " 5½″ "
24	193536	439·9	12·91	14·5	1·045	¾″ " 5″ "

Table (12)—Load = 250 lbs. per sq. ft.

Span in ft.	B. M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	9375	96·7	2·84	4·0	·230	3/8″ at 5½″ centres.
6	13500	116·4	3·42	4·5	·277	3/8″ " 4½″ "
7	18375	135·5	3·98	5·0	·322	3/8″ " 4″ "
8	24000	155·0	4·55	5·5	·368	½″ " 6″ "
9	30375	174·6	5·13	6·5	·415	½″ " 5½″ "
10	37500	193·6	5·69	7·0	·461	½″ " 5″ "
11	45375	213 0	6·26	7·5	·506	½″ " 4½″ "
12	54000	232·4	6·83	8·0	·553	½″ " 4″ "
13	63375	251·6	7·39	8·5	·598	½″ " 3½″ "
14	73500	271 2	7·97	9·0	·645	5/8″ " 5½″ "
15	84375	290 4	8·52	9·5	·690	5/8″ " 5″ "
16	96000	310 0	9·11	10·5	·753	5/8″ " 4½″ "
17	108375	329·2	9·67	10·0	·783	5/8″ " 4½″ "
18	121500	348·6	10·24	11·5	·829	5/8″ " 4″ "
19	135375	367·8	10·80	12·5	·874	5/8″ " 4″ "
20	151000	388·7	11·42	13·0	·924	¾″ " 5½″ "

Table (13)—Load = 300 lbs. per sq. ft.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	11250	106·0	3·21	4·5	·260	⅜″ at 5″ centres.
6	16200	127·5	3·74	5·0	·303	⅜″ ,, 4″ ,,
7	22050	148·2	4·35	5·5	·352	½″ ,, 6½″ ,,
8	28800	169·8	4·97	6·0	·402	½″ ,, 5½″ ,,
9	36450	191·0	5·41	6·5	·438	½″ ,, 5″ ,,
10	45000	212·0	6·2[illegible]	7·5	·504	½″ ,, 4½″ ,,
11	54450	233·4	6·86	8·0	·555	½″ ,, 4″ ,,
12	64800	254·6	7·48	8·5	·606	⅝″ ,, 6″ ,,
13	76050	276·0	8·11	9·5	·656	⅝″ ,, 5½″ ,,
14	88200	297·0	8·53	10·0	·691	⅝″ ,, 5″ ,,
15	101250	318·2	9·35	11·0	·757	⅝″ ,, 4½″ ,,
16	115200	339·4	9·95	11·5	·806	⅝″ ,, 4½″ ,,
17	130050	360·8	10·60	12·0	·858	⅝″ ,, 4″ ,,
18	145800	381·8	11·20	13·0	·907	¾″ ,, 5½″ ,,
19	162450	403·0	11·84	13·5	·959	¾″ ,, 5½″ ,,
20	180000	424·4	12·47	14·0	1·010	¾″ ,, 5″ ,,

Table (14)—Load = 336 lbs. per sq. foot.

Span in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	12600	112·2	3·29	4·5	·266	⅜″ at 4½″ centres.
6	18144	134·6	3·95	5·0	·320	⅜″ ,, 4″ ,,
7	24696	157·6	4·61	6·0	·373	½″ ,, 6″ ,,
8	32256	179·4	5·27	6·5	·426	½″ ,, 5½″ ,,
9	40824	202·2	5·94	7·0	·481	½″ ,, 4½″ ,,
10	50400	224·6	6·60	8·0	·534	½″ ,, 4″ ,,
11	60984	247·0	7·26	8·5	·587	½″ ,, 4″ ,,
12	72576	269·3	7·91	9·0	·640	⅝″ ,, 5½″ ,,
13	85176	291·8	8·55	10·0	·694	⅝″ ,, 5″ ,,
14	98784	314·6	9·25	10·5	·749	⅝″ ,, 4½″ ,,
15	113400	336·8	9·90	11·5	·801	⅝″ ,, 4½″ ,,
16	129024	359·6	10·57	12·0	·855	⅝″ ,, 4″ ,,

Table (15)—Load = 400 lbs per sq. ft

Span in ft.	B.M. inch lbs.	$\sqrt{B. M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	15000	122·8	3·71	5·0	·300	$\frac{3}{8}''$ at 4″ centres.
6	21600	147·0	4·32	5·5	·350	$\frac{1}{2}''$ „ $6\frac{1}{2}''$ „
7	29400	171·8	5·05	6·5	·409	$\frac{1}{2}''$ „ $5\frac{1}{2}''$ „
8	38400	196·0	5·76	7·0	·465	$\frac{1}{2}''$ „ 5″ „
9	48600	220·5	6·48	7·5	·524	$\frac{1}{2}''$ „ $4\frac{1}{2}''$ „
10	60000	245·0	7·20	8·5	·583	$\frac{1}{2}''$ „ 4″ „
11	72600	269·5	7·90	9·5	·639	$\frac{5}{8}''$ „ $5\frac{1}{2}''$ „
12	86400	294·0	8·64	10·0	·699	$\frac{5}{8}''$ „ 5″ „
13	101400	318·5	9·37	10·5	·759	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
14	117600	343·0	9·98	11·5	·808	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
15	135000	367·5	10·80	12·0	·874	$\frac{5}{8}''$ „ 4″ „
16	153600	392·0	11·52	13·0	·932	$\frac{3}{4}''$ „ $5\frac{1}{2}''$ „

Table (16)—Load = 448 lbs. per sq. foot.

Span in ft.	B.M. inch-lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	167921	129·6	3·81	5·0	·307	$\frac{3}{8}''$ at 4″ centres.
6	24192	155·4	4·55	6·0	·368	$\frac{1}{2}''$ „ 6″ „
7	32928	181·4	5·33	6·0	·431	$\frac{1}{2}''$ „ 5″ „
8	43008	207·4	6·09	7·5	·493	$\frac{1}{2}''$ „ $4\frac{1}{2}''$ „
9	54432	233·2	6·85	8·0	·554	$\frac{1}{2}''$ „ 4″ „
10	67200	259·3	7·62	9·0	·617	$\frac{5}{8}''$ „ $5\frac{1}{2}''$ „
11	81312	285·2	8·38	9·5	·678	$\frac{5}{8}''$ „ 5″ „
12	96768	311·0	9·13	10·5	·739	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
13	117568	342·8	10·07	11·5	·815	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
14	131712	363·0	10·69	12·5	·864	$\frac{5}{8}''$ „ 4″ „
15	151200	388·8	11·42	13·0	·924	$\frac{3}{4}''$ „ $5\frac{1}{2}''$ „

Table (17).—Loads = 500 lbs. per sq. foot.

Span. in ft.	B.M. inch lbs.	$\sqrt{B.M.}$	d inches.	h inches.	A_t sq. inches.	Diam. and spacing of Reinforcement.
5	18750	137·0	4·02	5·5	·325	$\frac{1}{2}''$ at 7″ centres.
6	27000	164·5	4·83	6·0	·391	$\frac{1}{2}''$ „ 6″ „
7	36750	191·6	5·43	6·5	·439	$\frac{1}{2}''$ „ 5″ „
8	48000	219·2	6·42	7·5	·520	$\frac{1}{2}''$ „ $4\frac{1}{2}''$ „
9	60750	246·8	7·25	8·5	·587	$\frac{1}{2}''$ „ 4″ „
10	75000	274·0	8·05	9·5	·652	$\frac{5}{8}''$ „ $5\frac{1}{2}''$ „
11	90750	301·5	9·15	10·5	·741	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
12	108000	328·0	9·64	11·0	·780	$\frac{5}{8}''$ „ $4\frac{1}{2}''$ „
13	126750	356·0	10·48	12·0	·848	$\frac{5}{8}''$ „ 4″ „
14	147000	385·8	11·32	13·0	·916	$\frac{5}{8}''$ „ 4″ „
15	168750	410·8	12·07	13·5	·977	$\frac{3}{4}''$ „ 5″ „

Simple Rule.—

For a load of 100 lbs. per ft. on floor. The thickness of floor $=\frac{1}{24}$th span where $B.\ M. = \frac{W.L.}{10}$

For $B.\ M. = \frac{W.L.}{12}$, decrease the span by 10%

and $B.\ M. = \frac{W.L.}{8}$, increase the span by 10%

Thus a continuous beam will have a thickness of 5″ on 10 ft. span, while the same thickness will be enough on 11 ft. span for a simply supported beam; and for semi-continuous beams 5″ thick slab will be required on 9 ft. span.

For bigger loads, increase the thickness in proportion to the square root of the load. Thus, for 400 lbs. per ft. on a 11 ft. span we require—

$$\sqrt{\frac{400}{100}} \times 5'' = 2 \times 5 = 10''\ \text{slab.}$$

Referring to table for 400 lbs. we find the slab thickness of 9·5″ on 11 ft. span; thus our result is approximately correct.

Note:—For full details consult "Reinforced Concrete Design" by S. L. Bhatia.

Calculation for columns or posts.

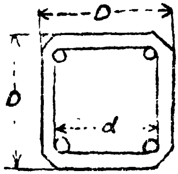
How to calculate a rectangular column or post made of good 1 : 2 : 4 ballast concrete reinforced with mild steel.

Let W = centrally applied load on column in lbs.
A_c = area of concrete in sq. inches.
A_t = sectional area of steel in sq. inches.

$$\text{Then } A_t = \frac{\frac{W}{500} - A_c}{14.} \qquad (1)$$

EXAMPLE.—Column 12 inches sq. has to carry a centrally applied load of 80,000 lbs. What should be the sectional area of the steel reinforcement?

$$A_t = \frac{\frac{80,000}{500} - 144}{14} = 1·14$$



This area of metal should be distributed among 4 rods placed at the corners of the posts; in this example four $\frac{5}{8}$ in. dia. round rods will do.

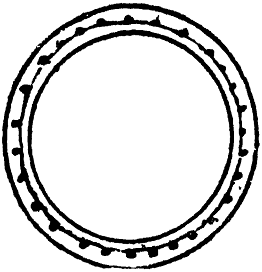
The longitudinal rods should be bound round with $\frac{3}{16}$ in. dia., wire loops or hooping spaced not more than 12 inches apart.

Table of Safe Loads on Columns.

Main Steel, 4 Bars.			Safe Load in Tons. On square column having side.										
Dia.	Area.	Wt.	8	9	10	11	12	13	14	15	16	17	18
Inch.	Sq. in	lb.											
½	·785	3·1	20	25	..	..	..	..	..	..	..	..	..
⅝	1·23	4·8	22	26	32	38	43	..	..	..	..	..	..
¾	1·77	6·9	24	28	34	39	45	53	60	..	..	..	..
⅞	2·42	9·4	26	31	37	42	49	55	62	70	78	..	..
1	3·14	12·3	29	34	39	45	51	58	64	77	81	90	94
1⅛	3·98	15·5	..	37	42	48	54	61	66	79	83	93	101
1¼	4·91	19·2	..	41	46	51	58	66	68	82	87	96	106
1½	7·08	27·6	..	..	..	60	65	72	86	86	91	103	114

8 Bars.													
Dia.	Area.	Wt.	13	14	15	16	17	18	19	20	21	22	23
½	1·57	6·2	50	..	..	..	..	..	..	..	..	..	..
⅝	2·45	9·6	55	62	70	75	..	..	..	..	..	..	..
¾	3·55	13·9	59	68	75	80	91	100	110	125	135	145	..
⅞	4·81	18·8	64	72	78	84	96	105	115	132	143	155	165
1	6·29	24·8	70	79	82	88	102	110	121	136	148	160	169
1⅛	7·95	31·2	75	83	91	98	109	117	128	142	155	165	178
1¼	9·88	38·4	82	90	95	105	115	125	137	152	165	174	185
1½	14·1	55·0	..	..	113	122	130	140	151	160	170	182	195

PIPES AND CIRCULAR RESERVOIRS.



Showing method of Reinforcement.

(*a*) Internal pressure.

If H = head of water in feet

L = width of strip considered in inches usually taken as 12 inches.

d = internal diameter of the pipe in inches.

A_t = area of steel reinforcement in 12″ width.

$$T = \frac{1}{2} p\, d = \frac{1}{2} W\, H\, d$$
$$= \frac{1}{2} \times 62\tfrac{1}{2}\, H.\, d$$
$$= 31\tfrac{1}{4}\, H\, d \text{ ft. lbs.}$$
$$= \cdot 215\, H\, d \text{ inch lbs. per ft. length.}$$

$$A_t = \frac{T}{t} = \frac{\cdot 215\, H\, d\, L}{t} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

and $d = \sqrt{\dfrac{\text{Capacity in gallons}}{4 \cdot 91\, H}}$

For circular bins and silos if p is the pressure on the sides in lbs. per sq. inch $A_t = \dfrac{P\, d\, L}{2\, t}$ .. .. (2)

The value of t should not be greater than ¾th the safe working resistance under flexure or 12,000 lbs. per sq. inch for mild steel.

(*b*) External pressure.

In this case as the structure is in compression we may allow for the resistance of the concrete.

$$P = \frac{1}{2} p\, D \qquad D = \text{External diameter in ft.}$$

The method of treatment is as follows :—

As the shell and longitudinals are continuous we may consider the slab as securely fixed at the ends and therefore the B. M. will be

$$\text{B. M.} = \frac{W\, L^2}{12} \text{ (at fixed ends).}$$

$$= \frac{W\, L^2}{24} \text{ (in the middle.)}$$

In addition to the hoop or spiral reinforcement determined above, longitudinal bars are necessary to strengthen the concrete to resist the pressure they have to sustain.

Practical considerations generally decide the thickness of the concrete shell which is usually 1½ to 2 inches thick for pipes up to 10 inches diameter and seldom exceeds 3 to 3½ inches even for larger diameter pipes.

For reservoirs the minimum thickness should be

h = Depth of tank	3	6	9	12	15 ft.
t = thickness	3	4	5	6	7 inches

$$t = \frac{h}{36} + 2 \text{ inches.}$$

REINFORCED CONCRETE ARCHES.

(*a*) Small span arches:—Arches with uniformly distributed load are considered as parabolic—

If W = load per square unit.
L = span
r = rise.
H = horizontal thrust

$$H = \frac{W L^2}{8 r} \quad \cdots \quad \cdots \quad (1)$$

Let R = Reaction at springings.

$$R \quad \frac{W L^2}{8r} \sqrt{1 + \frac{16r^2}{L^2}} \quad \cdots \quad \cdots \quad (2)$$

(*b*) Arches loaded over half the span and considered parabolic—

$$H = \frac{L^2}{16r}(w + 2p) \quad \cdots \quad \cdots \quad (3)$$

$$R \quad \frac{L^2}{16r}(w + 2p) \sqrt{1 + \frac{4r^2}{L^2} \left\{ \frac{(3w + 4p)^2}{(w + 2p)^2} \right\}} \quad (4)$$

The dead load produces no bending moment as it is uniformly distributed. The maximum bending moment due to super-imposed load only is produced at a section a quarter the length of the span from the springings tending to cause a downward deflection on the loaded side and an upward deflection on the unloaded side.

$$B.M. = \frac{WL^2}{64} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad (5)$$

The thrust at $\frac{1}{4}$ L from the springings is—

$$\frac{WL^2}{16r}(W + 2p) \sec \theta \quad \cdots \quad (6)$$

Where θ is the angle of the neutral surface curve to the horizontal.

The simplest method for finding the amount of reinforcement necessary and one sufficiently approximate for practical purposes is to first consider the direct thrust and find the intensity of stress c on the concrete due to the above. After this has been done, find the necessary reinforcement to resist the bending moment using the formula for beams, but with a maximum compressive resistance of concrete of $(600-c)$ and for the allowable resistance of the reinforcement. $16{,}000+15c$

EXAMPLE:—To find the necessary reinforcement for an arch to resist a B.M. of 300,000 inch lbs. and a normal thrust of 36,000 lbs. Radial depth 25 inches.

Consider 12″ strip of arch.

The stress due to thrust $= \dfrac{36{,}000}{25 \times 12} = 120$ lbs. per sq. ft.

The resistance for Bending = 600—120 = 480 lbs. per sq. ft.

The resistance for Reinforcement = 16,000 + 15 × 120 = 17,800 lbs.

For arches a symmetrical double reinforcement is generally employed.

We then have a double reinforced beam with $A_c = A_t$, 12″ wide, 25″ deep

with reinforcement near both surfaces under a bending moment of 300,000 inch lbs. when $t = 17{,}800$ lbs. per sq. inch.

$c = 480$ lbs. per sq. inch.

$d = 23$ inches.

$$n = \frac{15\,c\,d}{t+15c} = \frac{15 \times 480 \times 23}{17{,}800 \times 15 \times 480} = \frac{165600}{25000} \quad 6{\cdot}6''$$

Place the reinforcement bars 2″ for the top $C_s = 15 \times c \dfrac{n-d_c}{n}$

$$Cs = 15 \times 480 \times \frac{4{\cdot}4}{6{\cdot}6} = 4{,}800 \text{ lbs. per sq. inch.}$$ (See formula 7a double reinforced beams.)

$$\text{B. M.} = \tfrac{1}{3}\,c\,n^2\,b + C_s\,A_c\,(n-d_c) + t\,A_t\,(d-n) \quad \left\{\begin{array}{c}\text{Equation 5 double}\\ \text{reinforced beam}\end{array}\right\}$$

$$300{,}000 = \tfrac{1}{3} \times 480 \times (6{\cdot}6)^2 \times 12 + 4800\,A_t\,(6{\cdot}6 - \frac{6{\cdot}6}{3})$$
$$+ 17{,}800\,(23 - 6{\cdot}6)\,A_t$$

$$= 160 \times 43{\cdot}56 \times 12 + 4{,}800\,A_t \times 4{\cdot}4 + 17{,}800 \times 16{\cdot}4\,A_t$$

$$= 83635{\cdot}20 + 21{,}120\,A_t + 291{,}920\,A_t$$

$$2{,}16{,}365 = 3{,}12{,}040\,A_t$$

$$A_t = {\cdot}69 \text{ sq. inches}$$

Use ½″ rod 3″ apart. (See table No. 18)

h_s = depth at springing in ft.

If h_c = depth at crown in ft.

$$h_c = \frac{(\text{Span in ft})^2}{9{,}600} + {\cdot}66 \text{ ft.} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$h_s = h_c \sec\beta \text{ and } \beta = \tan^{-1} \frac{14 \times \text{rise}}{\text{Span}} \text{ approx.} \quad \ldots \quad (8)$$

horizontal thrust at springing $= H \times \sec\beta$ .. .. (9)

Width at the Crown $= 2 \times h_c$ .. .. (10)

Table (18) *giving sectional area of metal in 12 inches width of slab with the rods spaced various distances apart.*

Diameter of rods, inches.	Sectional area in sq. inches.	SECTIONAL AREA OF ROUND BARS IN 12 INCH WIDTH OF SLAB WHEN SPACED AT													
		3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10
¼	·0491	·196	·166	·147	·130	·118	·106	·098	·090	·080	·078	·070	·068	·060	·059
5/16	·0767	·307	·260	·230	·204	·184	·168	·153	·142	·130	·120	·115	·108	·102	·092
⅜	·1104	·442	·376	·331	·294	·265	·240	·221	·204	·188	·176	·165	·156	·147	·132
7/16	·1503	·601	·510	·451	·400	·36	·326	·301	·278	·255	·240	·225	·212	·200	·180
½	·1963	·785	·668	·589	·524	·471	·428	·393	·364	·334	·314	·295	·278	·262	·235
9/16	·2485	·994	·844	·745	·662	·596	·540	·497	·460	·422	·396	·372	·314	·331	·298
⅝	·3068	1·227	1·042	·920	·818	·736	·670	·613	·568	·521	·492	·46	·434	·406	·368
11/16	·3712	1·485	1·262	1·114	·990	·891	·808	·742	·69	·631	·594	·557	·526	·495	·445
¾	·4412	1·767	1·502	1·325	1·178	1·06	·964	·884	·82	·751	·706	·662	·626	·589	·530
13/16	·5185	2·074	1·760	1·550	1·382	1·244	1·128	1·037	·958	·881	·828	·777	·734	·691	·622
⅞	·6013	2·405	2·044	1·80	1 604	1·44	1·320	1·203	1·112	1·022	·962	·902	·852	·80	·721
15/16	·6903	2·761	2·346	2·071	1·84	1·65	1·510	1·38	1·276	1·170	1·104	1·035	·978	·92	·828
1	·7854	3·142	2·67	2·356	2·094	1·88	1·702	1·57	1·452	1·33	1·256	1·178	1·11	1·05	·940
1⅛	·9940	3·976	3·38	2·98	2·650	2·38	2·096	1·99	1·85	1·69	1·59	1·45	1·40	1·33	1·19
1¼	1·227	4·91	4·172	3·682	3·272	2·94	2·674	2·45	2·27	2·09	1·96	1·84	1·73	1·64	1·47
1½	1·767	7·071	6·06	5·36	4·71	4·24	3·852	3·53	3·12	3·03	2·82	2·65	2·5	2·35	3·12

ROADS.

Material.—Stone, hard Moorum, Kankar or Latrite.

Barrow-pits.—No barrow-pits to be within 10 feet from the foot of the slope of embankment.

Demarcation of Boundaries.—Furlong stones on either sides.

Width of Roadway.—Ordinary Indian roads are from 12 to 20 feet.

Road side Drains.—1 to 3 feet below the surface of road, 2′ wide paved on its floor and inner side.

Catch-water Drains.—Should be constructed alongside the roadway at a distance of 10 to 40 feet above the roadway.

Gradient.—Maximum 1 in 20 with not less than 300 feet of level length in each mile. Steeper than 1 in 30 should be avoided if possible. In America the ruling gradient is 1 in 11. For camel load the ruling gradient to be 1 in 10 : max. 1 in 8. For mule load ruling gradient to be 1 in 7 : max. 1 in 5.

Curves.—Should not be less than 60 feet radius except at re-entering angles. In all curves sharper than 100′ radius the rise in 100 feet should be $\frac{1}{20}$ radius. On camel roads the curves are not to be less than 10 feet radius.

Super-elevation.—The pitch of the banking should vary inversely with the radius of curve.

Banking.—On all curves of more than 45° the surface should be banked inwards at a slope of 1 in 20 and on still sharper curves at a slope of 1 in 12.

Approaches to Bridges.—Approaches should be as easy as possible.

Blind Corner.—Corners should be so laid out that a 4 feet rod placed at the centre of a road may be visible from the same height, 100 feet away.

Wheel Guards and Bump Posts.—Should be fixed at both ends of all bridges and culverts. They may consist of old rails or stones projecting at least 9″ beyond the inner edge of the parapet or coping. Wheel guards or kerbs 9″ high and 9″ wide should also be provided along the edges of the roads for the full length of the parapet or railings.

Pitch	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{9}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{12}$	$\frac{1}{14}$	$\frac{1}{16}$	$\frac{1}{20}$
Radius of Curve ..	36	56	65	80	100	120	150	200	250	400

Annual Wear of Roads in India.—Is reckoned at one cubic yard of broken metal per mile annually for each cart that passes over such mile daily (Molesworth).

Camber.—Normal in straight roads 1 in 40. No camber on curves. Excessive camber should be avoided , it is dangerous to swift traffic.

Loss of Power on inclines :—Calling the load which a horse can draw on level 1

on a rise of 1 in 100	a horse can draw only	0·90
„ „ 1 in 50	„ „	0·81
„ „ 1 in 44	„ „	0·75
„ „ 1 in 40	„ „	0·72
„ „ 1 in 30	„ „	0·64
„ „ 1 in 26	„ „	0·54
„ „ 1 in 20	„ „	0·40
.. .. 1 in 10	.. ..	0·25

The force or pull which a horse has to exert to draw a load on a level macadamized road varies from $\frac{1}{18}$ to $\frac{1}{25}$ of the load according to the condition of road.

The figures in table below, are generally adopted at the relative tractive force necessary to draw a load on different kinds of materials composing of road surface.

Materials.	Resistance to traction on level.	Tractive force in lbs. required to move one ton on a level.
Asphalted roads	1·0 to 1·5	15 to 22·5
Paved roadway, dry and in good order ..	1·5 to 2·0	22·5 to 30·0
,, ,, ,, ,, fair order ..	2·0 to 2·5	30·0 to 37·5
,, ,, ,, ,, covered with mud ..	2·0 to 2·7	30·0 to 40·5
Macadamized roadway, dry and in good order ..	2·5 to 3	37·5 to 45
,, ,, in wet state ..	3·3	49·5
,, ,, ,, fair order ..	4·5	67·5
,, ,, ,, covered with mud ..	5·5	82·5
,, ,, ,, covered with loose sand	5 to 8·2	75 to 123
Katcha Roads	13—18	200—250
Rails	1·0	15

Traction or Friction on Roads.

Cart on common road .. .. .. = $\frac{1}{30}$ load.

Carriage on plank road .. .. .. = $\frac{1}{100}$ load.

Carriage on rail road .. .. .. = $\frac{1}{300}$ load.

The load (in addition to cart) two bullocks can safely draw on a level each working day is—

On sand road	228 lbs.
ordinary earth	456
worn stone blocks	1,137
hard earth	1,193
hard gravel	1,279
hard macadam	1,391
best stone block	3,006
asphalts	6,095 ,, (Morin Gordon).

Grade Table.

Inclination 1 in	Angle with horizon.	Rise per mile in feet.	Inclination 1 in	Angle with horizon.	Rise per mile in feet.
	° ′			° ′	
5	11—18½	1056	33	1—44½	160
7	8—7½	754	35	1—38¼	151
8	7—7½	660	37	1—33	143
10	5—43	528	40	1—26	132
11	5—12	480	43	1—16½	123
12	4—46	440	45	1—10½	117
13	4—24	406	50	1—8	105½
14	4—5¼	377	55	1—2½	96
15	3—49	352	60	0—57¼	88
16	3—34½	330	70	0—49	75½
17	3—22	311	80	0—43	66
18	3—11	293	90	0—38¼	59
19	3—1	278	100	0—34½	53
20	2—51½	264	110	0—31¼	48
22	2—36	240	115	0—30	46
24	2—23	220	120	0—28½	44
25	2—17½	211	125	0—28	42
27	2—7	195½	150	0—23	39½
28	2—2	188½	200	0—17¼	26½
30	1—54½	1[illegible]3	400	0—8½	13

Table of Coefficients of Friction.

1. Wood on wood or metal.—Dry, ·4 to ·6; greasy, ·2 to ·4; lubricated, ·1 to ·2.
2. Metal on Metal.—Wet, ·3; dry, ·2; greasy, ·15; lubricated, ·1; standing or ·08, moving.
3. Leather on Metal.—Wet, ·25; dry, ·5.
4. Stone on wrought iron.—dry, ·6; wet, ·3; greasy, ·17.
5. Stone on stone.—Dry, ·65; wet, ·33; greasy, ·16.

Approximate Cost of Roads.

The approximate cost of roads is Rs. 20,000/-per mile in the Punjab.

For rough estimates in a 16 feet road the following are approximately of equal cost :—

Embankment, 4 feet high	..One mile.
Culverts (aggregate spans) ..	..36 feet.
Large bridge	..10 feet run.
Maintenance	..900 feet (Roorkee Treatise).

Large span road bridges cost approx. Rs. 100/- to Rs. 150/- per foot run.

Construction.

Soling.—Should always be provided except on rocky soil. It should be 1 foot more than the required width of the road.

Thickness of Soling.—Normal 6 to 9 inches. On embankments 9 to 12 inches, should be hand packed.

Metalling.—The gauge of the metal should be 1½ to 2 inches.

Consolidation.—Consists of (1) spreading and rolling dry; (2) watering and rolling wet; (3) surfacing and rolling wet.

Parapets and hand rails should be 2 feet thick and 3 feet high. If stones are used, each stone should be of such size that one man cannot move it.

Direction and Warning Signals.

1. Road direction post.
2. Warning signs and notices.
3. Village and place name signs.
4. Road name signs.
5. Mile stones and furlong stones.

Repairs to Metal.—The annual allowance for petty repairs is approx. 1,760 cubic feet per mile.

Road Records.—Record plan should be maintained for every road on a scale of 12 inches to one mile. It should show all important particulars of road including gradients, radius of curves, metal stacking, catch-water drains, miles and furlong stones, boundary of road, culverts, causeways, bridges, buildings, wells, cross-roads and other important objects.

Remetalling.—Normal period 4 years. The thickness of metal should not be allowed to get less than 2 to 3 inches. Process consists of—

1. Scouring the old surface.
2. Spreading the new metal.
3. Dry rolling
4. Watering and wet rolling.

Special Methods of Road Surfacing.

1. Oil and tar spraying.
2. Tar macadam.
3. Cement concrete.
4. Reinforced brick and concrete.
5. *Asphalte and Maxsphalte.*

1. Tar oiling comprises the pressure spraying of the surface with a suitable number of coats of tar oil or petroleum oil with a mixture of 5 % coal tar. The following condition must be fulfilled:—

1. The surface must be dry and clean.
2. Traffic must be kept off the portion.
3. Should be carried out only in dry hot weather. The mixture should be applied hot at 200° F.

Three coats are necessary. The first coat requires 10 tons, second 5 tons and the third coat 4 tons in case of 12 feet road one mile long or say 2 to 3½ lbs. per square yard. The first coat requires 2 days to dry, the second 4 days, and the third 7 to 10 days. After 3 coats no watering is required for a year.

It is said that tar spraying gives a slippery road. This can be overcome by the use of a larger grade and greater quantity of chippings. The use of bitumen or a mixture of bitumen and tar instead of tar, reduces slipperiness to a great extent.

2. *Tar Macadam* is superior to oil spraying but more expensive in initial cost. Following conditions should be fulfilled:—

1. Should have a proper foundation.
2. The thickness of surface coating to be not less than 3 inches.
3. The aggregate should consist of 60% 2″ standard gauge, 30% 1½″, 10% of ¾″ to ½″.
4. The stone must be thoroughly dried before being coated with tar.
5. The quantity used to coat one ton of metal should be approximately from 9 to 12 gallons.
6. Too much rolling should be avoided.
7. Stone chipping ¼″ should be used for gritting.

In the districts where stone is available a water bound road sealed with a mixture of bitumen and tar is the most economical form of construction. Such a road if properly maintained will last a considerable time and cost less in maintenance. Hard stone should be used if available. In places where stone is not available and transporting is expensive, bitumen macadam mixed by machinery or asphaltic concrete is more economical. The methods of constructing these roads are more expensive than water bound macadam, but the total weight of material to be transported to the site is less, the life is longer and the cost of maintenance low.

Another type of construction for such places is bitumen macadam using well burnt brick ballast for the base instead of stone. Increase the quantity of bitumen and thickness of top coat.

3. *Cement Concrete.*—It is durable and well suited for high speed traffic. The initial cost is great but the maintenance is less. Thickness to be 6 to 8 inches according to soil. The stone should be graded from 1½ inches to ⅜ inch. Usual proportion 1 : 2 : 4. In case where two courses are essential, the upper should be richer in thickness of 1½ inches, composed in proportion 1 : 1 : 2 or 1 : 1½ : 3.

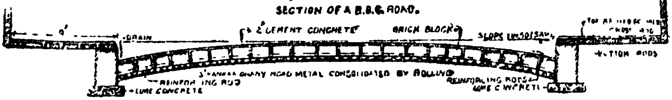
4. ***Reinforced brick roads*** are equally strong and durable as reinforced concrete but cost much less. The cost of maintenance is practically nothing.

Method of Construction.—(1) Make net-work of steel and place the same on the road bed ½″ above the ground. (2) Insert hard-burnt bricks in the spaces between steel rods taking care that they remain free from contact of rods and where blocks are used with two or more bricks, they can be made separately beforehand and then placed in position. (3) Pour ½″ cement mortar of wet consistency in the joints. (4) Lay cement concrete at the top of the bricks to the required depth and keep the surface covered with sand till the concrete sets hard.

5. *Proportion.*— *i.* 1 : 2½ or 2 cement mortar.

ii. 1 : 2 : 3. Cement concrete.

REINFORCED BRICKWORK CONCRETE ROADS
(PLAIN OR ASPHALTED)
SECTION OF A B.B.C. ROAD.



Sealing Coat on Water Bound Macadam.

This should only be applied where the surface is in good order and perfectly dry. Sweep the road surface free from all dirt and dust. Heat the tar to a temperature of 230° F. to 240° F. Apply the tar to the road surface covering about 40 s. ft. to the gallon. Cover with chippings of hard broken stone or gravel of the following grades:—

Passing ¼″ screen, 0 to 15 per cent.

Passing ½″ screen, 25 to 75 per cent.

Passing ¾″ screen, 95 to 100 per cent.

Use sufficient chippings to cover up the tar completely and roll them on well with a roller. Apply another coat six to twelve months later. This should be similar to the first coat except that instead of ta a mixture of 2 parts bitumen and 3 parts of tar should be used, heated to a temperature of 350° F. Further applications are made from time to time.

5. *Asphalt and Maxsphalt Roads.*

General.—Bitumen is obtainable in various grades of hardness. In Great Britain bitumen, having a penetration of from 50 to 75 is used for macadam and concrete. For sealing bitumen with penetration of 90 to 200 is used. A grade should be selected such that the hottest time of the year, it should never be so soft as to be liable to serious corrugation. For Punjab a grade with a penetration of 40 to 50 will be found suitable.

General Description of Specification.—This specification covers the construction of sheet asphalt surface course and applies only when the materials used meet the requirements of the standard specified. It is the intent and purpose of the specification to cover specially the standards of materials to be used and the arrangement thereof in such a manner as to furnish a dense and compact sheet asphalt surface. This specification does not comprehend the preparation of the base course sub-grade method of draining.

Composition of Mixture.—The sheet asphalt surface mixture shall consist of sand and mineral filler, uniformly mixed with asphalt and laid to the required thickness.

Materials : Sand.—The sand for the sheet asphalt surface mixture shall consist of clean, hard, durable grains free from clay, loam or other foreign matter. When tested by means of laboratory screens, the sand shall consist of one or more commercial products and shall be considered as passing the openings of a sieve having 10 meshes to an inch.

Mineral Filler.—The mineral filler of sheet asphalt surface mixture shall consist of thoroughly dry limestone dust or Portland Cement free from clay, loam or other foreign matter passing a sieve having 30 meshes to an inch and at least 65% of which shall pass through the sieve having 200 openings to an inch.

Asphalt.—The asphalt used under these specifications shall be steam refined asphalt prepared from crude asphaltic base petroleum. It shall be homogeneous, free from water, and shall not foam when heated to 175° C. or 347° F. It shall meet the following requirements for physical and chemical properties.

Purity.—(1). It shall not be less than 99 % soluble in cold carbonate sulphide (CS_2.)

Penetration.—(2). The penetration at 25° C. or 77° F. of 100 grammes shall be between the limits of 5 to 6 millimeters.

Ductility.—(3). The ductility at 25° C. or 77° F. shall not be less than 100.

Volatility.—(4). The loss on heating at 163° C. or 320° F. for five hours shall not be more than 3%.

Flash point.—(5). Shall not be less than 175° C. or 347° F.

Solubility.—(6). The solubility in cold carbon tetra chloride (CC_{44}) shall not be less than 99 %.

Preparation of Asphalt.—The asphalt shall be heated in kettle or tanks designed to secure uniform heating of entire contents and shall be brought to a temperature of 225° F. to 350° F.

Prepgration of Sand and Filler.—The sand for the sheet asphalt surface mixture shall be dried and heated at the paving plant in suitable designed revolving drums and shall be heated to a temperature of 275° F., or 375° F. as determined

on the mixing platform. When a mixture of 2 or more sands is required in order to produce a material conforming to the preparation of good asphalt, such comnation shall be made before the sand is fed into the driers in proper proporbitions. Immediately after heating the sand shall be screened into sizes as follows:—

(1) Passing sieve having 10 meshes to a inch retained on a sieve of 40 meshes. (2) Passing the 40 mesh sieve and retained on 80 mesh sieve. (3) Passing 80 mesh sieve and retained on 200. (4) Passing 200 mesh sieve.

The screened material is to be stored in 4 separate lines according to sizes above specified. The mineral filler shall be stored separately. It shall be fed directly into the mixer or shall be thoroughly mixed with sand from 10 to 15 seconds before the asphalt is added.

An approved device shall be installed at suitable point at the discharged end of the drier, for clearly indicating to the drum fireman the temperature of the sand as discharged.

Preparation of Surface Mixture.—The sand for the sheet asphalt mixture shall be measured separately by weight for each batch. The mixed filler shall be added by sacks of definitely known weight. The sand mineral filler shall be mixed in accordance with the quantities and sizes as described above.

The required quantity of hot asphalt from each batch shall be measured by actual weighing with the scales attached to the asphalt buckets. The sand and mineral filler shall be thoroughly mixed in such a way that all particles of sand and filler are uniformly coated in less than a minute.

The time of mixing should be at the discretion of engineer.

Paving Plant Inspection.—The engineer or his authorized representative shall have access at any time to all parts of the paving plant for the verification of the weight, properties and character of materials, and determination of temperatures used in the preparation of mixture.

Transportation of Mixture.—The sheet asphalt surface mixture shall be transported from the paving plant to the work in tight vehicles previously cleared of all foreign material and, when directed by the engineer, each load shall be covered with canvas or other suitable material of sufficient size to protect it from weather conditions. In case oil is used to prevent the adhesion of the mixture to the bed of the truck, an excess oil shall not be permitted. No loads shall be sent out so late in the day as to interfere with spreading and compacting the mixture during day light unless artificial light to the satisfaction of the engineer is provided.

Construction.—Prior to the arrival of the mixture on the work the prepared base shall be cleared of all loose and foreign materials. The mixture shall be delivered at the temperature of 250° to 325° F.

Upon arrival on the work it shall at once be uniformly spread by means of shovels, forks or mechanical spreader in a loose layer to correct depth over the area designated. No mixture shall be spread when the base is wet or when weather condition is unsuitable.

Completing Mixture.—When still hot the sheet asphalt surface course shall be thoroughly and uniformly compressed by a power driven roller of 6 to 8 tons.

Rolling shall start longitudinally at the sides and proceed towards the centre of the pavement overlapping on successive trips by at least half the width of the roller. Until thoroughly consolidated the motion of the roller shall at all times be slow enough to avoid displacement of the hot mixture and any displacement occurring as the result of reversing the direction of the roller or from any other cause, shall at once be corrected by the use of rakes and a fresh mixture when required. The rolling shall proceed at an average rate not exceeding 200 square yards per hour per roller except a gasoline roller of the approved type is used: in which case 250 square yards per hour per roller shall be allowed and shall continue until no further impression is possible. The wheels of the roller shall be properly moistened to prevent adhesion of the surface of the mixture to the roller, but an excess of water shall not be allowed.

Before final compression a light uniform coating of limestone dust or cement shall be swept over the surface of the pavement and the rolling then continued for another 2 to 3 times.

Along kerbs, headers and similar structures and at places not suitable to the roller the surface mixture shall be thoroughly compacted with hot tempers to provide sealed joints.

The surface of the mixture after compression shall be smooth and true to the established crown to grade. Any mixture which becomes loose or broken or in any way defective shall be immediately remedied by removing the surface course mixture at such spots and by replacing it with fresh hot sheet asphalt which shall be immediately compacted to conform with the surrounding area.

Joints in Surface Course.—The placing of the sheet asphalt mixture shall be as nearly continuous as possible and the roller shall pass over the unprotected and the fresh laid mixture only when the laying of this course is to discontinue for such a length of time as to permit the mixture to become chilled. In such cases, including the formation of joints, provision shall be made for proper bond with new surface mixture by cutting or trimming back the joints while the material is still hot; so as to expose a granular surface for the full specified depth of the course.

At the end of the last day's work, when the laying of the surface mixture is resumed the exposed edge of the joints should be painted with a thin coat of hot asphalt and the fresh mixture shall be raked against the joint thoroughly.

Protection of Pavement.—Sections of newly compacted sheet asphalt wearing surface course shall be protected from traffic for at least six hours or until they have become properly hardened by cooling.

Construction of Surface Course.—The constituents of the asphaltic concrete surface mixture shall be combined in such proportions as to produce a mixture conforming to the following composition limits by weight :—

Passing 1″ square sieves and retain on ½″	..25 to 35 %.
Passing ½″ square sieves and retain on ¼″	..15 to 25 %.
Passing ¼″ square sieves and retain 10 meshes	..10 to 20 %.
Passing 10 mesh	..25 to 35 %.
Mineral filler	.. 0 to 6 %.
Asphalt	.. 5 to 8 %.

The following figures will serve as a guide :—

(*a*) (1) Course stone	..	..	480 lbs.	54·6 %
(2) Fine stone	..	..	200 „	22·7 %
(3) Sand	..	..	150 „	12 %
*(4) B. A. Cement	..	..	50 „	5·7 %
	Total	..	880 lbs.	
(*b*) (1) Course stone	..	..	480 lbs.	53·3 %
(2) Fine stone	..	..	202 „	22·4 %
(3) Sand	..	..	150 „	16·2 %
†(T) A. Cement	..	..	68 „	7·6 %
	Total	..	900 lbs.	

How to use asphalt by penetrating method.

(1) Using ungraded road metal.

Spread dry clean $1\frac{1}{4}''$ to $2\frac{1}{4}''$ stone bottom course in such a quantity that after being rolled there will be a depth of not less than $2\frac{1}{2}''$, nor more than $3''$.

Roll until stones do not creep under action of roller. Pour $1\frac{1}{2}$ to $1\frac{3}{4}$ gallons of asphalt heated to not less than 325° F. into each square yard of road surface.

Spread clean dry $\frac{3}{4}''$ stones evenly over surface and roll thoroughly; after which remove all loose stones whioh have been not driven into the road.

Apply to this surface $\frac{1}{2}$ gallon of asphalt per square yard, cover with dry clean screenings and roll until a smooth surface results.

The road may be opened to traffic as soon as completed.

(2) Using graded road metal.

The stones shall be of a good quality and of two gradings hereafter known as " A " and " B ".

" A " stones shall be graded as follows :—

Passing sieve of mesh.	Retained on sieve mesh.	Percentage weight.	
2	..	100	
2	$1\frac{1}{2}$	22 to 32	} 50 to 68
$1\frac{1}{2}$	$1\frac{1}{4}$	13 to 17	
$1\frac{1}{4}$	1	15 to 19	
1	$\frac{3}{4}$	16 to 22	} 35 to 47
$\frac{3}{4}$	$\frac{1}{2}$	19 to 25	

*B. A. C=Bermaudez Asphalt Cement.

†T. A. C=Trinded Asphalt Cement.

"B" stones shall be graded as follows:—

$\frac{1}{2}$	$\frac{3}{8}$	12 to 16	48 to 64
$\frac{3}{8}$	$\frac{1}{4}$	14 to 18	
$\frac{1}{4}$	$\frac{1}{8}$	17 to 23	
$\frac{1}{8}$	10	5 to 7	
10	20	10 to 14	19 to 29
20	30	5 to 7	
30	40	3 to 5	
40	50	1 to 3	15 to 25
50	80	3 to 5	
80	100	1 to 3	
100	200	3 to 5	

If "A" stones contain 50 to 68% of stones passing a 2″ sieve but retained on a 1″ sieve and from 35 to 47 % passing 1″ but retained on 1½″ sieve it hall be acceptable.

Construction.—Upon the foundation grade "A" stone shall be spread evenly to a depth of 2″.

The surface shall be rolled with a 8 to 12 ton steam roller until thoroughly consolidated.

Liquified asphalt at a temperature 425° F. shall then be evenly applied over the surface at the ratio of ¾ Imperial gallons per square yard with hand or mechanical pressure distributor.

Sufficient grade "B" stone shall be spread over the surface to fill all interstices.

The surface shall be again rolled until thoroughly consolidated.

All surface stones shall be removed from the surface by sweeping.

The surface shall now be painted with liquid asphalt and to ensure an even distribution, push brooms shall be used.

The surface shall now be thoroughly covered with grade "B" stones and rolled again as before. Alternate rolling and covering with grade "B" stones shall be continued until the road is firm and smooth. Any spots too rich in asphaltun shall be covered with grade "B" stone and rolled, and any spots too dry shall have asphaltun applied and grade "B" stone spread over it and rolled.

Cost Rs. 6-12-0 per square yard.

∴ Cost per mile of 16 feet wide road=Rs. 63,750 approximate as compared to the cost of ordinary water bound macadam which is = Rs. 20,000 under ordinary conditions.

No hard and fast rules can, however, be laid. It differs in different places and depends upon the hardness of stone metal and the lead from the quarry.

Maxphaltic Groutings.

Asiatic Petroleum Company supplies this in about 375 lbs. casks.

Specification of Products:—

Specific gravity at 77° F.	1·05
Melting point	160° F.
Penetration at 77° F. 100 grammes wt. 5 seconds	26
Ductility at 77° F.	14
Bitumen soluble in CS_2	99·9 %
Insoluble inorganic matter	·05
Ashes	·05
CS_2	28·4

The following may be taken as an approximate specification for the manufacture of two course road work to comprise of a binder course of say 2″ with carpet of 1¼″.

	Binder Course.	Surface Course.
Bitumen	5 %	10·5 %
Filler	5 %	14·0 %
Sand	20 %	-- %
Chippings	-	12·8 %

NOTE.—Rate of Maxphalt is Rs. 7/12/0 per cwt. as delivered from docks.

This is a simple and economical method of construction of an impervious surface and capable of carrying heavy mechanical traction. The only plant required consists of boilers having a large heating area and cans with roses.

A good hard rock broken to 2″ gauge should be evenly and carefully spread. The metal should be lightly rolled, just sufficient to place each stone in its proper place; care should be taken that no maxphalt is applied when the stone is wet. Maxphalt heated to a temperature of 350° F. should be poured into the interstices, great care being taken to ensure even distribution.

Approximately 2 gallons of maxphalt should be used per square yard for a 3″ consolidated coating of metal. It is the practice of many Engineers to then sprinkle chippings over the grouted surface and to continue rolling while others prefer to allow the maxphalt to cool slightly and then roll. The former is better in author's opinion. The sealing coat should consist of "Spramax," a semi-solid bitumen having a penetration of 200, heated to 350° F. or maxphalt fluxed to a penetration of 200, and applied by means of pails.

Immediately after the application of spramax a dressing of chippings should be spread, one ton of spramax will seal about 600 to 700 square yards.

Cost.—The average cost of grouting a 3″ macadam as above described is Rs. 2/6/0 per square yard above the ordinary cost of water bound macadam.

It has long been recognized that tar is not altogether satisfactory for road surface dressings, for various reasons upon which it is unnecessary to dilate. A series of experiments have been carried out by Shel-Max Ltd., with a view to find a substitute having greater advantages. This material marked under the name of Spramax has been found to answer every test applied as a surface dressing and subsequently dressing with clean chippings. It gives an asphaltic wearing surface and is far better than tar.

Asphaltic Concrete Mixers.—These can be used either for asphaltic concrete or bituminous macadam. The larger sizes are of the stationary type, but the smaller ones are portable. The latter type is suitable for Indian conditions. The most common size is one with an output of 8 to 10 tons per hour, but a smaller size producing about half this quantity is also manufactured. This latter size will probably be found the best for use in the Punjab at least until experience has been gained. The general lines of the mixers by various British manufacturers are similar. The aggregate is fed in at ground level, elevated, passed through a drying and heating drum, elevated again into a bin, and passed through a hand operated shutter into a hopper in which it is weighed. There is also a pan in which the hot bitumen and tar are weighed; the material can be laddled out of the melter into this pan by hand. The pan and hopper can each be emptied into the mixer by moving a lever. The filler is emptied direct into the mixer by hand. The mixed concrete is discharged by moving a lever into a vehicle waiting below. The 4-5 ton per hour machine requires about 16 B. H. P.

Rollers.—A great diversity of types and weights of rollers is in use in Great Britain. An 8-ton tandem steam roller is probably the most convenient for asphaltic concrete. Steam steering gear is a great convenience for this work. In no case should the roller be so heavy as to break the stone. Whatever type of roller is used, reversing should be instantaneous. When rolling asphaltic concrete the rollers should be kept damp to prevent them sticking to the bitumen.

The following is a list of the plant required for mixing and laying bituminous macadam or asphaltic concrete:—

Asphalt mixing plant, 4 ton per hour capacity.
Portable steam engine, 10 B. H. P.
or
Oil engine, 16 B. H. P.
Two 500 gallon bitumen melting tanks.
Tar boiler, 250 gallons capacity.
Thermometers reading to 600° F.
Smoothers.
Tampers.
Rakes.
Bitumen boilers.
8 Ton Tandem Steam Roller.
1 Ton lorries with iron bodies.

RAILWAYS.

Gauge:—The gauge of a railway is the distance between the two rails forming the track. It is measured between the inner sides of the rail heads.

Table Showing Railway Gauges used in different countries.

	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
India	5	6	3	3⅜	2	6	2	0
Australia	5	3	4	8½	3	6	2	6
Belgium	4	8½	..		..		..	
Canada	4	8½	..		..		..	
Ceylon	5	6	..		..		..	
China	5	0	4	8½	..		..	
Denmark	4	8½	..		..		..	
France	4	9⅛	4	8½	3	3⅜	..	
Germany	4	8½	3	3⅜	2	5½	..	
Ireland	5	3	3	0	..		..	
Japan	3	6	2	6	2	0	..	
Malay	3	3⅜	..		..		..	
Newzealand	3	6	..		..		..	
Newfoundland	3	6	..		..		..	
Portugal	5	5¾	3	3⅜	..		..	
Russia	5	0	..		..		..	
South America practically all gauges.								
South Africa	3	6	2	0	..		..	
Spain	5	5¾	3	3⅜	..		..	
Sweden	4	8½	3	6	2	11	..	
Switzerland	4	8½	3	3⅜	..		..	
Tasmania	3	6	..		..		..	
United States America ..	4	8½	3	0	..		..	

Max. and Min. Dimensions to be observed on all Broad, Meter and Narrow gauge Railways in India.

Items.	Broad gauge 5′-6″	Metre gauge 3′-3⅜″	Narrow gauge 2′-6″
Formation.—Min. width in embankment (Single Line) ..	20	16	10
Min. width in cutting (Single Line) ..	18	14	9
Min. width in embankment (Double Line)	34	28	22
Min. width in cutting (Double Line) ..	32	26	21
Curves.—Max. degree of curvature on main line—			
(*a*) For unlimited speeds ..	5°-0′	8°-0′	10°-0′
(*b*) Under any circumstances ..	10°-0′	16-0′	48°-0′
Min. Radius—			
(*a*) Unlimited speed	ft. 1146	716	573
(*b*) Under any circumstances ..	ft. 573	358	120
Transition Approaches :—			
The length of transition curve for unrestricted speeds per degree of Curvature	ft. 50	30	15
Ballast.—Min. width at top ..	ft. 11	7½	6
Min. depth below sleepers ..	8″	6″	6″
Sleepers, wooden—section ..	10″ × 5″	8″ × 4½″	7″ × 4½″
Min. Length	ft. 9-0	6′-0	5′-0
No. of sleepers per mile (Min.) ..	1906	1906	..
No. of sleepers per mile (Usual) ..	2112	2112	..
Max. distance apart centre to centre	..	..	2′-9″
Min. distance apart in bridges when resting on Longitudinal girders	2½′	1½′	..
Rails.—Min. weight of Rail per yard for axle load of :—			
tons cwt.			
12 0 ..	60	..	..
13 10 ..	65	..	..
15 2 ..	70	..	..
17 0 ..	75	..	..
18 12 ..	80	..	..
20 8 ..	85	..	..
22 12 ..	90	..	..
24 14 ..	95	..	..
26 18 ..	100	..	..
Min. clearance of guard-rail for curves and level crossings ..	2″	2″	2″
Min. depth of space for wheel flange from rail level ..	1⅛″	1⅜″	1¼″

Max. and Min. Dimensions to be observed on all Broad, Meter and Narrow gauge Railways in India.—contd.

	5′-6″	3′-3⅜″	2′-6″
Spacing of Tracks:—			
Min. distance, centre to centre of tracks outside station limits ..	ft. 14	12	12
Gradients in Stations:—			
Max. in Station yards, on single line to 150 feet beyond the outermost points, and on double line from home signal to last stop signal for each line	1 in 1,000	1 in 1,000	1 in 400
Station Buildings:—			
Min. horizontal distance from centre of tracks to any structure—			
(*a*) For rail level to 1 ft. above rail level ..	5′-6″	4′-5″	..
(*b*) Except a platform, from rail level to 9′-6″ above rail level			6′-0″
Standard height, passenger platform above rail ..	2′-9″	1′-4″	1′-4″
Alternative height, passenger platform, aboverail ..	1-′4″	1′-0″	1′-0″
Hieght for goods carriage and horse	3′-6″	2′-0″	..
Ends of platform to be ramped not steeper than ..	1 in 7	1 in 7	..
Min. distance of building from end of passenger platforms ..	24′	24′	18′
Max. length of passenger platform ft.	600	600	
Min. length of passenger platforms ..	400′	400	
Min. height above rail of roof in passenger stations ..	20′	18′	
Min. height above rail of overbridges	14′-6″	12′-6″	
Min. height above rail of wires crossing the line ..	20′	20′	
Min. distance centres of passenger tracks ..	15′	15′	
Min. distance centres of other sidings	13½′	13½′	
Min. distance centres of sidings for spare stock ..	12′	12′	
Min. radius points and crossings ..	660′	330′	
Usual radius points and crossings ..	800′	600′	
Standard angles of crossings 1 in.	6, 8½, 12	6¾, 9½, 12,	7, 10, 12
Standard lengths of tongue rails ..	12′-15′	9′-12′	
Water tank—Minimum height, bottom of tank from rail ..	25′	20′	15′
Min. total tank capacity at any Station	2,000 gallons to 12,500 gallons.	1,000 gallons to 6,250 gallons.	00 gallons to 3,125 gallons.

Max., Min. Dimensions to be observed on all Broad, Meter and Narrow gauge Railways in India—concld.

Items.	5′-6″	3′-3⅜″	2′-6″
Ashpits, etc. :—			
Average depth of Ashpits in Station yards ..	2′-6″	3′-6″	..
Clear length at bottom of Ashpits ..	65′	50′	15′
Average depth of examining pits for Carriages and Wagons and of pits in running shed ..	2′-6″	3′-0″	3′-9″

Minimum quantity of ballast =14 cubic feet per foot lineal of Railway.

Side-drains and catch water drains in all cases to vary according to circumstances.

In hard soil no lining will be required to the side-drains, and where required, the lining to vary according to the materials to be obtained.

Surface of the ballast to be drained carefully if retentive.

Top ballast to be of such a size as to be capable of being passed in every position through a ring 2½″ diameter.

Bottom ballast to be capable of being passed in every position through a ring, 4″ diamter.

Length of wooden sleepers should be $=G \times 1{\cdot}72$ (G.=Gauge used)
=9½ ft. for the 5′ 6″ gauge.
=6′-8″ for the metre gauge line.

Weight of Rail per yard:—

$$W=11{\cdot}5\sqrt{L.\ S.}$$

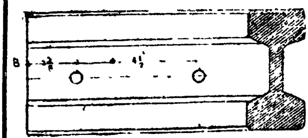
Where W=Weight of rail in lbs. per yard.
L=Maximum load per axle in tons.
S=distance centre to centre of sleepers in ft. usual 2′-6″.

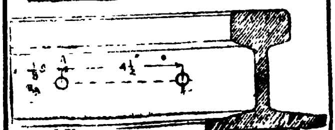
Weight for weight, Bull-head and flat-bottom rails may be taken to be of equal strength.

British Standard B. H. and F. B. Rail Sections.

Weight in lbs. per yard.	BULL HEAD RAILS.		FLAT BOTTOM RAILS.	
	Head. H.	Depth. D.	Head. H.	Flang + Depth. F.
100	$2\frac{3}{4}''$	$5\frac{29}{32}''$	$2\frac{3}{4}''$	$5\frac{3}{4}''$
95	$2\frac{3}{4}''$	$5\frac{23}{32}''$	$2\frac{11}{16}''$	$5\frac{9}{16}''$
90	$2\frac{3}{4}''$	$5\frac{35}{64}''$	$2\frac{5}{8}''$	$5\frac{3}{8}''$
85	$2\frac{11}{16}''$	$5\frac{15}{32}''$	$2\frac{9}{16}''$	$5\frac{3}{16}''$
80	$2\frac{9}{16}''$	$5\frac{3}{8}''$	$2\frac{1}{2}''$	$5''$
75	$2\frac{1}{2}''$	$5\frac{1}{8}''$	$2\frac{7}{16}''$	$4\frac{13}{16}''$
70	$2\frac{7}{16}''$	$5''$	$2\frac{3}{8}''$	$4\frac{5}{8}''$
65	$2\frac{3}{8}''$	$4\frac{7}{8}''$	$2\frac{5}{16}''$	$4\frac{7}{16}''$
60	$2\frac{5}{16}''$	$4\frac{3}{4}''$	$2\frac{1}{4}''$	$4\frac{5}{16}''$
55	..	..	$2\frac{5}{32}''$	$4\frac{1}{8}''$
50			$2\frac{1}{16}''$	$3\frac{15}{16}''$
45			$3\frac{31}{32}''$	$3\frac{3}{4}''$
40			$1\frac{7}{8}''$	$3\frac{1}{2}''$
35			$1\frac{3}{4}''$	$3\frac{1}{4}''$
30			$1\frac{5}{8}''$	$3''$
25			$1\frac{1}{2}''$	$2\frac{3}{4}''$
20			$1\frac{3}{8}''$	$2\frac{1}{2}''$
18			$1\frac{9}{32}''$	$2\frac{3}{8}''$
16			$1\frac{7}{32}''$	$2\frac{1}{4}''$
14			$1\frac{5}{32}''$	$2\frac{1}{8}''$
12			$1\frac{1}{16}''$	$1\frac{15}{16}''$
10			$\frac{15}{16}''$	$1\frac{13}{16}''$

B. H. Rails.

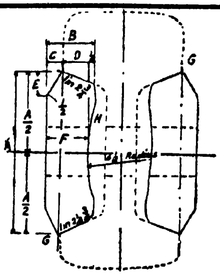




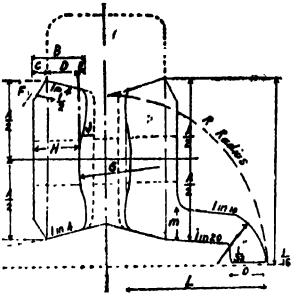
F. B. Rails.

Distance A B varies from $2\frac{1}{8}''$ to $1\frac{5}{8}''$

British Standard Fish Plate Sections.



	No. of B. S. Section of Rails.						
	70	75	80	85	90	95	100
	Dimensions in inches.						
A	$3\frac{7}{32}$	$3\frac{7}{32}$	$3\frac{7}{16}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$
B	1	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$
C	$\frac{9}{32}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{21}{64}$	$\frac{21}{64}$	$\frac{21}{64}$	$\frac{21}{64}$
D	$\frac{19}{32}$	$\frac{19}{32}$	$\frac{5}{8}$	$\frac{43}{64}$	$\frac{43}{64}$	$\frac{43}{64}$	$\frac{43}{64}$
E	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{17}{32}$
F	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	1	1	1	1
G	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{5}{64}$	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{64}$
H	$\frac{17}{64}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$



British Standard Fish Plate Sections—concld.

No. of B.S. Section of Rails.	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
A	1 3/4	1 57/64	2 3/64	2 15/64	2 23/64	2 1/2	2 5/8	2 3/4	2 31/64	2 15/16	3 1/16	3 3/16	3 5/16	3 7/16	3 37/64	3 11/16
B	4/16	39/64	21/32	45/64	3/4	51/64	27/32	57/64	15/16	63/64	1 1/32	1 5/64	1 1/8	1 11/64	1 2/32	1 17/64
C	1/16	3/64	3/64	3/64	5/64	3/32	7/64	7/64	11/64	13/64	15/64	17/64	9/32	19/64	5/16	21/64
D					37/64	19/32	5/8	43/64	41/64	21/32	43/64	11/16	25/32	3/4	25/32	13/16
E					3/32	7/64	7/64	7/64	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
F	3/8	9/32	9/32	9/32	5/16	3/8	7/16	7/16	19/64	23/64	13/32	29/64	31/64	33/64	35/64	9/16
G					1 7/8	2	2 1/4	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/4	3 1/2	3 3/4	4
H					21/32	11/16	47/64	25/32	13/16	53/64	29/32	61/64	1	1 3/64	1 3/32	1 9/64
I	1/8	1/8	1/8	1/8	5/32	5/32	5/32	5/32	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16
J	7/64	7/64	7/64	7/64	1/8	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
K	1 31/32	2 11/64	2 5/16	2 33/64	2 19/64	2 13/16	2 31/32	3 1/8	3 3/16	3 23/64	3 1/2	3 21/32	3 25/32	3 15/16	4 5/64	4 13/64
L	1 39/64	1 3/4	1 57/64	2 1/16	2 13/64	2 19/64	2 27/64	2 9/16	2 37/64	2 23/32	2 27/32	2 31/32	3 3/32	3 15/64	3 3/8	3 15/32
M	5/16	11/32	3/8	13/32	7/16	15/32	1/2	33/64	17/32	9/16	19/32	5/8	21/32	11/16	23/32	3/4
N	7/64	7/64	7/64	7/64	1/8	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
O	23/64	25/64	27/64	31/64	33/64	17/32	37/64	5/8	19/32	21/32	45/64	3/4	25/32	53/64	7/8	57/64
P	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4	5/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16
Q	3/4	3/4	3/4	3/4	7/8	7/8	7/8	7/8	1	1	1	1	1	1	1	1
R	1 27/32	2	2 5/32	2 11/32	2 33/64	2 5/8	2 49/64	2 29/32	2 31/32	3 1/8	3 17/64	3 13/32	3 17/32	3 43/64	3 13/16	3 59/64

Expansion of rails.

1. Proper allowance must be made for expansion, according to temperature as follows:—

Temp.	Ins.	Temp.	Ins.
100°	0	40°	
80°	$\frac{1}{16}$	20°	
60°		0°	

The thermometer to be read in shade.

Super-elevation.

The Super-elevation of the outer rail on a curve should correspond to the radius at every point. With circular curves this is impossible, but by using a transition curve it is possible to raise the outer rail gradually until the circular curve is reached, and the correct Super-elevation is obtained for the circular curve.

The following points should be always kept in view:—

1. The greatest elevation of outer rails on curves must not exceed 6″ unless otherwise directed.
2. The elevation of outer rails on curves must necessarily be adapted to speed and other local conditions, with due regard to safety, comfort and economy of track maintenance for all classes of trains.
3. The elevation on mountain grades should not exceed that required for 25 miles per hour.
4. The elevation must not be continued beyond the tangent point, but should decrease uniformly, along the easement curve from point of maximum curvature to tangent point.

The centrifugal force C tons of a moving train is calculated by the following formula:—

$$C = \frac{\text{Weight of train in tons} \times \text{square of velocity (ft. per sec.)}}{32{\cdot}2 \times \text{Radius of curve in ft.}}$$

The Superelevation is calculated by the following formula:—

$$E = \frac{G \times V^2.}{32{\cdot}2\ R.}$$

Where E = Super-elevation in inches.
G = Gauge in inches.
V = Velocity in ft. per sec.
R = Radius of curve in feet.

If the gauge is expressed in ft. and the velocity in miles per hour, then the formula becomes:—

$$E = \frac{G \times V^2.}{1{\cdot}25\ R.}$$

Table of Superelevation of outer rails on curves for various Radii and speed
2 ft. 6 in. gauge.

Radius of curve.		SPEED OF TRAIN IN MILES PER HOUR.				
		10	15	20	25	30
In chains.	In feet.	Super-elevation in inches.				
2	132	1½	..	..	..	..
2¼	148½	1⅜	3	..	..	..
2½	165	1¼	2¾	..	..	..
2¾	181½	1⅛	2½	..	..	..
3	198	1	2¼	..	..	..
3¼	214½	15/16	2⅛	..	..	..
3½	231	⅞	2	..	..	..
3¾	247½	13/16	1¾	..	..	..
4	264	¾	1¾	3	..	..
4¼	280½	¾	1⅝	2⅞	..	..
4½	297	11/16	1½	2¾	..	..
4¾	313½	11/16	1⅜	2½	..	..
5	330	⅝	1⅜	2⅜	..	..
5½	363	9/16	1¼	2¼	..	..
6	396	½	1⅛	2	..	..
6½	429	..	1 1/16	1⅞	3	..
7	462	..	1	1¾	2¾	..
8	528	..	⅞	1½	2⅜	..
9	594	..	¾	1⅜	2⅛	3
10	660	..	11/16	1¼	1⅞	2¾
11	726	..	⅝	1⅛	1¾	2½
12	792	..	9/16	1	1⅝	2¼
15	990	..	..	13/16	1¼	1¾
20	1320	..	..	⅝	1	1⅜
25	1650	..	..	½	13/16	1⅛
30	1980	..	..	..	⅝	⅞
40	2640	..	..	..	½	11/16
50	3300	..	..	..	..	9/16

Table giving Super-elevation of Outer Rail on Curves for various Radii and speeds Gauge 3 feet $3\frac{3}{8}$ inch.

Radius of Curves.		Speed of Train in Miles per Hour.					
		10	15	20	25	30	35
In. chain.	In ft.	Super-elevation in inches.					
3	198	$1\frac{3}{8}$	3	..	..	..	..
$3\frac{1}{4}$	$214\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	..	..	..	..
$3\frac{1}{2}$	231	$1\frac{1}{4}$	$2\frac{5}{8}$	..	..	..	..
$3\frac{3}{4}$	$247\frac{1}{2}$	$1\frac{1}{8}$	$2\frac{1}{2}$	..	..	..	..
4	264	1	$2\frac{1}{4}$	4	..	..	..
$4\frac{1}{4}$	$280\frac{1}{2}$	1	$2\frac{1}{8}$	$3\frac{7}{8}$	..	..	..
$4\frac{1}{2}$	297	$\frac{7}{8}$	2	$3\frac{1}{2}$	..	..	..
$4\frac{3}{4}$	$313\frac{1}{2}$	$\frac{7}{8}$	2	$3\frac{1}{2}$	..	..	..
5	330	$\frac{7}{8}$	$1\frac{7}{8}$	$3\frac{1}{4}$	..	..	..
$5\frac{1}{2}$	363	$\frac{3}{4}$	$1\frac{5}{8}$	3	..	..	..
6	396	$\frac{5}{8}$	$1\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{4}$	..	..
$6\frac{1}{2}$	429	$\frac{5}{8}$	$1\frac{1}{2}$	$2\frac{1}{2}$	4	..	..
7	462	$\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{3}{8}$	$3\frac{3}{4}$	..	..
8	528	..	$1\frac{1}{8}$	2	$3\frac{1}{4}$	..	..
9	594	..	1	$1\frac{7}{8}$	$2\frac{7}{8}$	4	..
10	660	..	1	$1\frac{5}{8}$	$2\frac{1}{2}$	$3\frac{3}{4}$	..
11	726	..	$\frac{7}{8}$	$1\frac{1}{2}$	$2\frac{3}{8}$	$3\frac{3}{8}$	..
12	792	..	$\frac{3}{4}$	$1\frac{3}{8}$	$2\frac{1}{8}$	3	$4\frac{1}{4}$
15	990	..	$\frac{5}{8}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$2\frac{3}{8}$	$3\frac{1}{4}$
20	1320	..	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{1}{2}$
25	1650	..	..	$\frac{3}{4}$	1	$1\frac{1}{2}$	2
30	1980	..	..	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{5}{8}$
40	2640	..	..	..	$\frac{5}{8}$	1	$1\frac{1}{4}$
50	3300	..	..	..	$\frac{1}{2}$	$\frac{3}{4}$	1
60	3960	..	..	..	..	$\frac{5}{8}$	$\frac{7}{8}$
80	5280	..	..	..	..	$\frac{1}{2}$	$\frac{5}{8}$
100	6600	..	..	..	..	..	$\frac{1}{2}$

Table of Super-elevation of Outer Rail on Curves for various Radii and speeds.
Gauge 5′—6″.

Radius of Curves. In Chains.	Radius of Curves. In ft.	Speed of Train in Miles per Hour. 15	20	25	30	35	40	45	50	60
		Super-elevation in inches.								
6	396	2⅝	..	..	..	..	..	..	..	..
6½	429	2⅜	..	..	..	..	..	..	..	..
7	462	2¼	4	..	..	..	..	..	..	..
8	528	2	3½	..	..	..	..	..	..	..
9	594	1¾	3⅛	..	..	..	..	..	..	..
10	660	1½	2¾	4⅜	..	..	..	..	..	..
11	726	1⅜	2½	4	..	..	..	..	..	..
12	792	1¼	2⅜	3⅝	..	..	..	..	..	..
15	990	1	1⅞	2⅞	4⅛	..	..	..	..	..
20	1320	¾	1⅜	2⅛	3⅛	4¼	..	..	..	..
25	1650	⅝	1⅛	1¾	2½	3⅜	4½	..	..	..
30	1980	½	⅞	1½	2⅛	2⅞	3¾	..	..	..
40	2640	..	¾	1⅛	1½	2⅛	2¾	3½	4⅜	..
50	3300	..	½	⅞	1¼	1¾	2¼	2¾	3½	..
60	3960	..	..	¾	1	1⅜	1⅞	2⅜	2⅞	4⅛
80	5280	..	..	½	¾	1	1⅜	1¾	2⅛	3⅛
100	6600	..	..	..	⅝	⅞	1⅛	1⅜	1¾	2½
120	7920	..	..	..	½	¾	⅞	1⅛	1½	2⅛
160	10560	..	..	..	..	½	¾	⅞	1⅛	1½

Rail Bending :—

$$V = \frac{3 \cdot C^2}{2R}$$

Where V=Versine in inches.
C=Length of rail in feet.
R=Radius in feet.
Example C=24 feet R=1,274 find V.

$$V = \frac{3 \times 24 \times 24}{2 \times 1{,}274} = \cdot 672 \text{ inches.}$$

The following table can also be used for finding the radius of curves and for checking the curvature of curves. A table to suit any particular radius not given in the following may be calculated by simple proportion.

Table of Rail Bendings.

Degree of curve.	Radius of curve in feet.	Length of Rails in feet.					
		36′	30′	28′	24′	23′	20′
		Middle ordinates in feet.					
0·5	11460	·0148	·010	·008	·005	·0049	·004
1·0	5730	·0296	·020	·016	·011	·010	·008
1·5	3820	·043	·029	·026	·018	·017	·013
2·0	2865	·0592	·038	·034	·025	·023	·017
2·5	2292	·074	·049	·043	·031	·029	·022
3·0	1910	·087	·058	·051	·037	·034	·026
3·5	1637	·1036	·070	·061	·043	·040	·031
4·0	1433	·116	·079	·069	·050	·046	·035
4·5	1274	·133	·088	·077	·056	·051	·039
5·0	1146	·148	·099	·086	·063	·058	·044
5·5	1042	·163	·108	·094	·070	066	·048
6·0	955·4	·174	·117	·102	·076	·070	·052
6·5	882·0	·191	·128	·112	·082	·075	·057
7·0	819·0	·207	·137	·120	·088	·081	·061
7·5	764·5	·221	·146	·127	·094	·086	·065
8·0	716·8	·232	·158	·187	·100	·092	·070
8·5	674·6	·251	·166	·145	·106	·098	·074
9·0	637·3	·265	·175	·153	·112	·103	·078
9·5	603·8	·281	·187	·163	·119	·110	·083
10·0	573·7	·296	·196	·171	·125	·115	·087
11·0	521·7	·326	216	·188	·139	·128	·096
12·0	478·3	·355	·236	·206	·151	·139	·105
13·0	441·7	·384	·254	·222	·163	·150	·113
14·0	410·3	·413	·275	·239	·175	·161	·122
15·0	383·1	·442	·295	·257	·188	·173	·131
16·0	359·3	·464	·313	·273	·200	·185	·139
17·0	338·3	·502	·333	·290	·213	·196	·148
18·0	319·6	·530	·351	·306	·225	·207	·156
19·0	302·9	·562	·371	·324	·238	·219	·165
20·0	287·9	·590	·392	·341	·250	·231	·174
21·0	274·4	·618	·410	·357	·262	·242	·182
22·0	262·0	·647	·430	·375	·275	·254	·191

RAILWAY CURVES.

Transition Curves—

On the straight both lines of railway track are laid at the same level. On a curve, however, the train is acted on by a horizontal centrifugal force of $\frac{W V^2}{g r}$ in addition to the vertical weight W.

The resultant of these forces should be at right angles to the line joining the tops of the rails in cross-section and this makes it necessary to place the outer rail on the curve higher than the inner one.

The difference of level is called the super-elevation of the outer rail and is given by the formula :—

$$E = \frac{(G+W) \times V^2}{g R}$$

Where—

E = super-elevation in inches

V = velocity in ft. per second

W = $\frac{1}{2}$ width of rail

G = gauge of railway in inches

R = Radius of curve in ft

g = 32·2 ft. per sec. per second.

If we pass directly from the straight to the circular arc we must begin to give this super-elevation while still on the straight, causing the train to lurch inwards. The full superelevation is not attained until some distance beyond the start of the curve, so that on entering the latter, there is a tendency to lurch outwards causing shaking and uneasy running.

To overcome this, it is the practice to introduce transition curves or spirals between the two. These start with a radius approaching infinity on joining the straight, while at the junction with the circular arc, the radius of curvature is the same as that of the arc.

Length of Transition Curves—

The principles, on which the length of a transition curve should be found, have been laid down by Mr. W. H. Shortt in the proceedings of the Institution of Civil Engineers.

The radial acceleration on the curve is $\frac{V^2}{r}$. Now Mr. Shortt considers that this for perfectly easy running, should be acquired at a rate not exceeding 1 foot per second per second.

Length of Transition Curves in feet per degree of curvature of circular curve :—

	Standard.	Metre.	Narrow.
For lines with unrestricted speed ..	100	35	..
For lines passed for traffic up to 30 miles per hour	35	20	..
Hill lines, or others passed for 20 miles an hour	15	12	6
„ „ 15 miles per hour ..	..	3	2
„ „ 10 „ „ „ ..	..	2 1/4	1
Standard gauge, 2 degree curve at 50 miles per hour	188	..	..
Standard gauge 8 degree curve at 20 miles per hour	..	125	..
Metre gauge, 4 degree curve 30 miles per hour	..	88	..
Metre gauge, 16 degree curve at 15 miles per hour	..	..	50
2′-6″ gauge, 48 degree curve 15 miles per hour	..	..	62 1/2

These figures are obtained by multiplying the Super-elevation by 25 to 50 as the case may be.

Table of Elevation of Outer Rails on Curves.

Degree of curvature.	RATE OF SPEED IN MILES PER HOUR.								
	15	20	25	30	35	40	45	50	60
	Superelevation in inches.								
1°	1/8	1/4	7/16	9/16	13/16	1 1/16	1 5/16	1 5/8	2 3/8
2°	5/16	1/2	13/16	13/16	1 5/8	2 1/8	2 11/16	3 5/16	4 3/4
3°	7/16	13/16	1 3/4	1 3/4	2 7/16	3 1/8	4	4 15/16	7 1/16
4°	9/16	1 1/16	1 5/8	2 1/8	3 1/4	4 3/16	5 5/16	6 5/8	..
5°	3/4	1 5/16	2 1/16	3	4	5 1/4	6 11/16	..	..
6°	7/8	1 9/16	2 7/16	3 9/16	4 13/16	6 3/8	..	..	..
7°	1 1/16	1 13/16	2 7/8	4 1/8	5 5/8	..	..	..	..
8°	1 3/8	2 1/8	3 5/16	4 11/16	6 1/2	..	..	..	..
9°	1 5/16	2 3/8	3 11/16	5 5/16	..	..	..	.	..
10°	1 1/2	2 5/8	4 1/8	5 15/16	..	..	..	..	..
12°	1 3/4	3 1/8	4 15/16	7 1/8	..	..	..	..	..
15°	2 3/16	3 15/16	6 3/16	..	..	..	..	..	..
18°	2 5/8	4 11/16	..	..	..	..	..	..	..
20°	2 15/16	5 1/4	..	..	..	..	..	..	..
Standard chord..	..	31·74′	39·68′	47·61	55·55	63·48	71·42	..	79·35

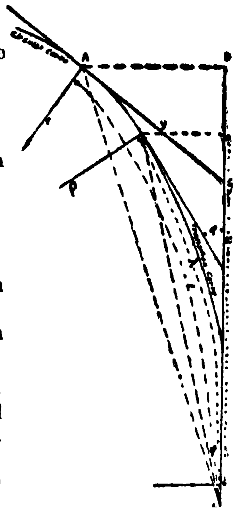
middle ordinate=proper elevation.

If L=length of curve

t=time taken to pass over it

$t=\frac{L}{v}$ and $t=\frac{v^2}{r}$, according to the above rule.

$\therefore L=\frac{v^3}{r}$ .. (1)



Max. super-elevation=7″ and W=2½″, we get on 5′-6″ guage.

$7=\frac{67\frac{1}{2} \times v^2}{32{\cdot}2 \times R}$ $\therefore v^2=R\times 3{\cdot}34$

$\therefore L=\sqrt{R}\times(3{\cdot}34)^{\frac{3}{2}}$

This gives minimum length for max. super elevation of 7″.

In practice $L=\sqrt{R}$ for circular curves of less than 57 chains.

Ideal Curve.—The super-elevation should be proportional to distance from starting point, so that the rail can be raised at a regular rate. But we have seen that it is inversely proportional to the radius of curvature, hence in the ideal curve the radius of curvature should be proportional inversely to the distance from starting point of transition curve or $\rho\lambda=C$ where ρ=radius of curvature, λ =distance from starting point. This is accurately satisfied in Crandall's curve and in Glover's spiral the equation of which is $\lambda=m\sqrt{\phi}$ where ϕ=angle between the straight and the tangent to the curve at a point whose distance from the start (measured round the curve) is λ

Glover's spiral—

$$\rho=\frac{d\lambda}{d\phi}$$

Hence $\rho=\frac{m}{2\sqrt{\phi}}=\frac{m}{2}\times\frac{m}{\lambda}=\frac{m^2}{2\lambda}$

But at the finishing point A of junction with the circular arc $\rho=r$ and $\lambda=L$.

$$\therefore r=\frac{m^2}{2L}$$

which gives value of m when r and L are known.

(2) Transition curve (cubic parabola) (*Molesworth*).

R=Radius of orginal curve.

E=Elevation of the outer rail.

L=Length of transition on each side of the origin.. angent point =200 E ; $=\sqrt{6RS}$.

S =Shift of altered curve=$L^2\div 6R$.

Y = Offset to transition curve.
$= x^3S \div 2L^3 = \frac{1}{2}$ S where x = L
Y = 4 S if x = 2L.

Speaking broadly, it may be said that it is only on curves of large radius that there is any great need for a transition curve : as these curves are associated with high speeds.

Points and Crossings.

Points or switches are the mechanical appliances by means of which a vehicle or a train is maintained on one line of rails at a junction or is diverted on to another line of rails.

A crossing, separated from the switch by a portion of straight or curved rail is the arrangement which permits of a wheel and flange passing across one or more rails which go to constitute one or more lines of railway.

The distance from the switch to the crossings is measured from the heel of the switch and not from the tongue.

Junctions (single).—The simplest form of junction is where a single branch line leaves one which is straight.

A radius commonly employed for such junction when used as a siding or cross-over road is 602 ft.

R = Radius of curve of outside rail

G = guage of railway,

a° = angle of crossing,

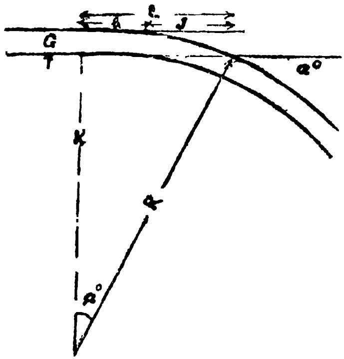
x = R. − G.

L = Length from tangent point of curve to centre of crossing,

l = length from tangent point to heel of switch

Then $L = \sqrt{(R + x)\ G} = 75' - 1{\cdot}7''$

$\text{Sin } a^\circ = \frac{L}{R}$ and $R = \frac{G}{\text{Versine } a^\circ}$



Curve Running from Reverse Curve.

Let R = Radius of inside rail of main curve,

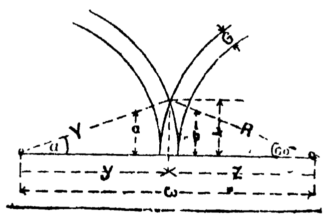
r = Radius of outside rail of branch curve,

G = guage of railway,

L = Length from tangent point of curve to centre of crossing,

w = Distance from centre to centre of radii,

M = Distance from point of crossing to nose as made,



Then $w = Z + Y = (R + r) - G.$

and $Z^2 - y^2 = R^2 - r^2$

$(Z + y)(Z - y) = R^2 - r^2$

$\therefore Z - y = \frac{R^2 - r^2}{w} = o \text{ if } R = r$

i.e. $w(z - y) = R^2 - r^2$

$Z = w - y = y \text{ if } R = r$

from these equations we can find Z and y

Then $L = \sqrt{(r^2 - y^2)} = \sqrt{(R^2 - Z^2)}$

$\text{Sin } a^\circ = \frac{L}{r} \quad \sin b^\circ = \frac{L}{R}$

angle of crossing $= a^\circ + b^\circ$

SIMPLE RULES.

(1) To set out a curve by offsets:—

Full offset for a chord of one chain of 66 ft. $= \frac{4{,}356}{R}$

Ditto ditto ditto 100 feet $= \frac{10{,}000}{R}$

Ex. :—Let R. $= 1{,}273 \cdot 2$ and chord $= 100$.

Then offset $= \frac{10{,}000}{1{,}273 \cdot 2} = 7 \cdot 85. = 7' \cdot 10\frac{1}{4}''.$

(2) To find the radius of a curve $R = \frac{15{,}000}{V}$

Where V = Versine in inches.

Approximate cost of one mile of Permanent Way 75 lbs. F.F. with bearing plates on deodar sleepers.

	Rs.
117·86 tons Rails at Rs. 150 per ton .. .. =	17,680
6·13 tons fish plates at Rs. 180 per ton .. .. =	1,103
1·46 tons fish bolts with nuts and washers at Rs. 400 per ton .. .. =	584
3·58 tons dog spikes at Rs. 300 per ton .. .. =	1,074
19·64 tons bearing plates at Rs. 280 per ton .. =	5,499
2,000 deodar sleepers at Rs. 8 each .. .. =	16,000
	40,940

Say Rs. 41,000 per mile.

Table of Corresponding Grades.

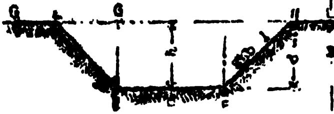
Grade 1 in.	Grade per cent.	Feet per mile.	Angle. °	′	″
1 in 1,000	·100	5·28	0	3	26
1 in 950	·105	5·56	0	3	37
1 in 900	·111	5·86	0	3	49
1 in 850	·118	6·21	0	4	3
1 in 800	·125	6·60	0	4	18
1 in 750	·133	7·04	0	4	35
1 in 700	·143	7·54	0	4	55
1 in 650	·154	8·12	0	5	17
1 in 600	·167	8·80	0	5	44
1 in 550	·182	9·60	0	6	15
1 in 500	·200	10·56	0	6	53
1 in 450	·222	11·73	0	7	38
1 in 400	·250	13·20	0	8	36
1 in 350	·286	15·09	0	9	49
1 in 300	·333	17·60	0	11	27
1 in 250	·400	21·12	0	13	45
1 in 200	·500	26·40	0	17	11
1 in 150	·666	35·20	0	22	55
1 in 125	·800	42·24	0	27	30
1 in 100	1·000	52·80	0	34	23
1 in 90	1·111	56·67	0	38	12
1 in 80	1·250	66·00	0	42	58
1 in 70	1·429	75·43	0	49	7
1 in 60	1·666	88·00	0	57	17
1 in 50	2·000	105·60	1	8	45
1 in 48	2·083	110·0	1	11	37
1 in 46	2·174	114·78	1	14	43
1 in 44	2·272	120·00	1	18	7
1 in 42	2·381	125·71	1	21	50
1 in 40	2·500	132·00	1	25	55
1 in 39	2·564	135·38	1	28	8
1 in 38	2·632	138·95	1	30	27
1 in 37	2·703	142·70	1	32	53
1 in 36	2·778	146·67	1	35	28
1 in 35	2·857	150·86	1	38	12
1 in 34	2·941	155·29	1	41	5
1 in 33	3·030	160·00	1	44	9
1 in 32	3·125	165·00	1	47	34
1 in 31	3·226	170·32	1	50	51
1 in 30	3·333	176·00	1	54	33
1 in 25	4·000	211·20	2	17	26
1 in 20	5·000	264·00	2	51	45

EARTH WORK.

First case

All Excavation

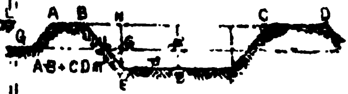
Area $= Bd + sd^2$



Second case

Part digging and part filling

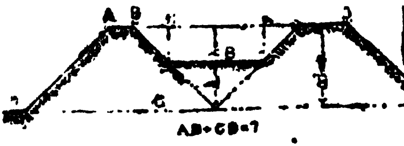
$$\text{Area} = \begin{cases} Bd + sd^2 + T(h - d) \\ \quad + 2s(h - d)^2 \end{cases}$$



Third case

All Bank

$$\text{Area} = \begin{cases} T(h+d) + 2s(h+a)^2 \\ \quad - \left(\begin{matrix}\text{Fig. E F M I} \\ Bd - sd^2\end{matrix}\right) \end{cases}$$

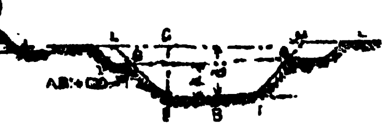


Fourth case

All digging with two Tow paths

B I + CK = B cut out at height h from bed

Area $= Bd + sd^2 + R(d - h)$



Areas of side slopes per foot length.

Depth, feet.	Slopes.					Depth, feet	Slopes.				
	½ to 1.	1 to 1.	1½ to 1.	2 to 1.	3 to 1.		½ to 1.	1 to 1.	1½ to 1.	2 to 1.	3 to 1.
0·1	·005	·01	·015	·02	·03	3·5	6·12	12·2	18·3	24·4	36·6
·2	·020	·04	·060	·08	·12	·6	6·48	13·0	19·5	26·0	39·0
·3	·045	·09	·135	·18	·27	·7	6·84	13·7	20·5	27·4	41·1
·4	·080	·16	·240	·32	·48	·8	7·22	14·4	21·6	28·8	43·2
·5	·125	·25	·375	·50	·75	·9	7·60	15·2	22·8	30·4	45·6
·6	·180	·36	·540	·72	1·08	4·0	8·00	16·0	24·0	32·0	48·0
7	·245	·49	·735	·98	1·47	·1	8·40	16·8	25·2	33·6	50·4
·8	·340	·68	1·02	1·36	2·04	·2	8·82	17·6	26·4	35·2	52·8
·9	·405	·81	1·21	1·62	2·43	·3	9·24	18·5	27·7	37·0	55·5
1·0	·500	1·0	1·50	2·00	3·00	·4	9·68	19·4	29·1	38·8	58·2
·1	·605	1·21	1·81	2·42	3·63	·5	10·1	20·2	30·3	40·4	60·6
·2	·720	1·44	2·16	2·88	4·32	·6	10·6	21·2	31·8	42·4	63·6
·3	·845	1·69	2·53	3·38	5·07	·7	11·0	22·1	33·1	44·2	66·3
·4	·980	1·96	2·94	3·92	5·88	·8	11·5	23·0	34·5	46·0	69·0
·5	1·12	2·25	3·37	4·50	6·75	·9	12·0	24·0	36·0	48·0	72·0
·6	1·28	2·56	3·84	5·12	7·68	5·0	12·5	25·0	37·5	50·0	75·0
·7	1·44	2·89	4·33	5·78	8·67	·1	13·0	26·0	39·0	52·0	78·0
·8	1·62	3·24	4·86	6·48	9·72	·2	13·5	27·0	40·5	54·0	81·0
·9	1·80	3·61	5·41	7·22	10·8	·3	14·0	28·1	42·1	56·2	84·3
2·0	2·00	4·00	6·00	8·00	12·0	·4	14·6	29·2	43·7	58·3	87·5
·1	2·20	4·41	6·61	8·82	13·2	·5	15·1	30·2	45·3	60·5	90·7
·2	2·42	4·84	7·26	9·68	14·5	·6	15·7	31·4	47·0	62·7	94·0
·3	2·64	5·29	7·93	10·6	15·9	·7	16·2	32·5	48·7	65·0	97·5
·4	2·88	5·76	8·64	11·5	17·3	·8	16·8	33·6	50·5	67·3	100·9
·5	3·12	6·25	9·37	12·5	18·7	·9	17·4	34·8	52·2	69·6	104·4
·6	3·38	6·76	10·1	13·5	20·3	6·0	18·0	36·0	54·0	72·0	108·0
·7	3·64	7·29	10·9	14·5	21·9	·1	18·6	37·2	55·8	74·4	111·6
·8	3·92	7·84	11·8	15·7	22·5	·2	19·2	38·4	57·0	76·9	115·3
·9	4·20	8·41	12·6	16·8	25·2	·3	19·8	39·7	59·5	79·4	119·1
3·0	4·50	9·00	13·5	18·0	27·0	·4	20·5	41·0	61·4	81·9	122·9
·1	4·80	9·61	14·4	19·2	28·8	·5	21·1	42·2	63·3	84·5	126·7
·2	5·12	10·2	15·1	20·4	30·8	·6	21·8	43·6	65·3	87·1	130·7
·3	5·44	10·9	16·3	21·8	32·7	·7	22·4	44·9	67·3	89·8	134·5
·4	5·78	11·6	17·4	23·2	34·8	·8	23·1	46·2	69·3	92·5	138·7

Areas of side slopes per foot length—contd.

Depth, ft.	Slopes.					Depth, ft.	Slopes.				
	½ to 1.	1 to 1.	1½ to 1.	2 to 1.	3 to 1.		½ to 1.	1 to 1.	1½ to 1	2 to 1.	3 to 1.
6·9	23·8	47·6	71·4	95·2	142·8	10·2	52·0	104·0	156·0	208·0	312·0
7·0	24·5	49·0	73·5	98·0	147·0	·3	53·5	106·1	159·1	212·2	318·3
·1	25·2	50·4	75·6	100·8	151·2	·4	54·1	108·2	162·3	216·4	324·6
·2	25·9	51·8	77·7	103·8	155·5	·5	55·1	110·2	165·3	220·4	330·6
·3	26·6	53·3	79·9	106·6	159·9	·6	56·2	112·4	168·6	224·8	337·2
·4	27·4	54·8	82·1	109·5	164·3	·7	57·2	114·5	171·6	229·0	343·2
·5	28·1	56·2	84·3	112·5	168·7	·8	58·3	116·6	174·9	233·2	349·8
·6	28·9	57·8	86·4	115·5	173·3	·9	59·4	118·8	178·2	237·6	356·4
·7	29·6	59·3	88·9	118·6	177·9	11·0	60·5	121·0	181·5	242·0	363·0
·8	30·4	60·9	91·2	121·7	182·5	·1	61·6	123·2	184·8	246·4	369·6
·9	31·2	62·4	93·6	124·8	187·2	·2	62·7	125·4	188·1	250·8	376·2
8·0	32·0	64·0	96·0	128·0	192·0	·3	63·8	127·7	191·5	255·4	383·0
·1	32·8	65·6	98·4	131·2	196·8	·4	65·0	130·0	195·0	260·0	390·0
·2	33·6	67·2	100·8	134·5	201·7	·5	66·1	132·2	198·3	264·4	396·6
·3	34·5	68·9	103·3	137·8	206·7	·6	67·2	134·5	201·7	269·0	403·4
·4	35·3	70·6	105·8	141·1	211·7	·7	68·5	137·0	205·5	274·0	411·0
·5	36·1	72·2	108·4	144·5	216·7	·8	69·6	139·2	208·8	278·4	417·6
·6	37·0	74·0	110·9	147·9	221·9	·9	70·8	141·6	212·4	283·2	424·8
·7	38·0	75·7	113·5	151·4	227·1	12·0	72·0	144·0	216·0	288·0	432·0
·8	38·7	77·4	116·2	155·0	232·3	·1	73·2	146·4	219·6	292·8	439·2
·9	39·6	79·2	118·8	158·4	237·6	·2	74·4	148·8	223·2	297·6	446·4
9·0	40·5	81·0	121·5	161·0	243·0	·3	75·6	151·5	226·9	302·6	453·8
·1	41·4	82·8	123·2	165·6	248·4	·4	76·9	153·8	230·7	307·6	461·4
·2	42·3	84·6	126·9	169·4	253·9	·5	78·1	156·2	234·3	312·4	468·6
·3	43·2	86·5	129·7	172·9	259·4	·6	79·4	158·8	238·2	317·6	476·4
·4	44·2	88·4	132·5	176·7	265·1	·7	80·6	161·3	241·9	322·6	483·8
·5	45·1	90·2	135·4	180·5	270·7	·8	81·9	163·8	245·7	327·6	491·4
·6	46·1	92·2	138·2	184·3	276·5	·9	83·2	166·4	249·6	332·8	499·2
·7	47·0	94·1	141·1	188·2	282·3	13·0	84·5	169·0	253·5	338·0	507·0
·8	48·0	96·0	144·1	192·1	288·1	·1	85·8	171·6	257·4	343·2	514·8
·9	49·0	98·0	147·0	196·0	294·0	·2	87·1	174·2	261·3	348·4	522·6
10·0	50·0	100·0	150·0	200·0	300·0	·3	88·0	176·9	264·0	352·0	528·0
·1	51·0	102·1	153·1	204·2	306·3	·4	89·8	179·6	269·4	359·2	538·8

Areas of side slopes per foot length—concld.

Depth, ft.	Slopes. ½ to 1.	1 to 1.	1½ to 1	2 to 1.	3 to 1.	Depth, ft.	Slopes. ½ to 1.	1 to 1.	1½ to 1	2 to 1.	3 to 1.
13·5	91·1	182·2	273·3	364·4	546·6	16·8	141·1	282·2	423·3	564·4	846·6
·6	92·5	185·0	277·5	370·0	555·0	·9	142·8	285·6	428·4	571·2	856·8
·7	93·8	187·7	281·5	375·4	563·0	17·0	144·5	289·0	433·5	578·0	867·0
·8	95·2	190·4	285·6	380·8	571·2	·1	146·2	292·4	438·6	584·8	877·2
·9	96·6	193·2	289·8	386·4	579·6	·2	147·9	295·8	443·7	591·6	887·4
14·0	98·0	196·0	294·0	392·0	588·0	·3	149·6	299·3	448·8	598·6	897·6
·1	99·4	198·8	298·2	397·6	596·0	·4	151·4	302·8	454·2	605·6	908·4
·2	100·8	201·6	302·4	403·2	604·8	·5	150·1	306·2	459·3	612·4	919·6
·3	102·4	204·5	306·3	409·0	612·6	·6	154·9	309·8	464·7	619·6	929·4
·4	103·7	207·4	311·1	414·8	622·2	·7	156·6	313·3	469·8	626·6	939·6
·5	105·2	210·5	315·7	421·0	631·4	·8	158·4	316·8	475·2	633·6	950·4
·6	106·6	213·2	319·8	426·4	639·9	·9	160·2	320·4	480·6	640·8	961·2
·7	108·0	216·1	324·1	432·2	648·2	18·0	162·0	324·0	486·0	648·0	972·9
·8	109·5	219·0	328·5	438·0	657·0	·1	163·8	327·6	491·4	655·2	982·0
·9	111·0	222·0	333·1	444·0	666·0	·2	165·6	331·2	496·8	662·4	993·6
15·0	112·5	225·0	337·5	450·0	675·0	·3	167·4	334·9	502·2	669·8	1004
·1	114·0	228·0	342·0	456·0	684·0	·4	169·3	338·6	507·9	677·2	1016
·2	115·5	231·0	346·5	462·0	693·0	·5	171·1	342·2	513·3	684·4	1027
·3	117·0	234·1	351·1	468·0	702·3	·6	173·0	346·0	519·0	692·0	1038
·4	118·6	237·2	305·8	474·4	711·6	·7	174·8	349·7	524·4	699·4	1049
·5	120·1	240·2	360·3	480·4	720·6	·8	176·7	353·4	530·1	706·8	1060
·6	121·7	243·4	365·1	486·8	730·2	·9	178·6	357·2	535·8	714·4	1072
·7	123·2	246·5	369·6	493·0	739·5	19·0	180·5	361·0	541·5	722·0	1083
·8	124·8	249·6	374·4	499·2	748·8	·1	182·4	364·8	547·2	729·6	1094
·9	126·4	252·8	379·2	505·6	758·4	·2	184·3	368·6	552·9	737·2	1106
16·0	128·0	256·0	384·0	512·0	768·0	·3	186·2	372·5	558·6	745·0	1117
·1	129·6	259·2	388·8	518·4	777·6	·4	188·2	376·4	564·6	752·8	1129
·2	131·2	262·4	393·6	524·8	787·2	·5	190·1	380·2	570·3	760·4	1141
·3	132·8	265·7	398·5	531·4	797·0	·6	192·0	384·1	576·1	768·2	1152
·4	134·5	269·0	403·5	538·0	807·0	·7	194·0	388·1	582·1	776·2	1164
·5	136·1	272·2	408·3	544·4	816·6	·8	196·0	392·0	588·0	784·0	1176
·6	137·8	275·6	413·4	551·2	826·8	·9	198·0	396·0	594·0	792·0	1188
·7	139·4	278·9	418·3	557·8	836·6	20·0	200·0	400·0	600·0	800·0	1200

These earthwork tables are sufficiently accurate for all practical purposes, unless the heights H and h at each end of any length differ greatly, and in that case a correction for the slopes is necessary. Thus if C and c be the cubic contents of the slopes corresponding to H and h in the tables, then the true contents will be $= x\,(\,C + c)$

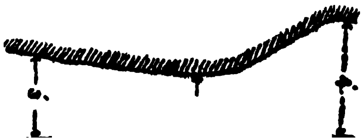
H	Values of x.					
50	·5					
40	·4959	·5				
30	·4804	·4933	·5			
20	·4483	·6767	·4872	·5		
20	·3973	·4118	·4333	· 4667	·5	
5	·3663	·3742	·3870	·4118	·1667	·5
0	·3333	·3333	·3333	·3333	·3333	·3333
Feet.	h=50	h=40	h=30	h=20	h=10	h=5

On side long ground where the areas are taken out from cross sections. If A and a be the areas of one slope at each end respectively, the cubic contents of the slope $= y\,(A + a)$

Table of values of y.

If $\frac{a}{A}$	·0	·05	·1	·15	·2	·25	·3	·35
then y	333	·404	·429	·445	·457	·466	·473	·479
If $\frac{a}{A}$	·4	·45	·5	·6	·7	·8	·9	1·
	484	·487	·490	·494	·497	·499	·4998	·5

Prismoidal Formula.



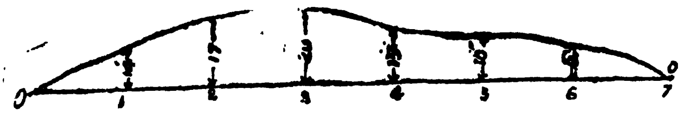
$C = \frac{1}{6}\,L\,(\,A + a + 4\,M)$

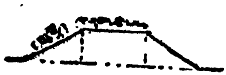
L = length of prism

c = contents of prism

A & a = area of ends of prism

Example.—To find the contents of a cutting whose longitudinal section and cross section is given below :—





Cubic contents of side slopes = 100 × 1855

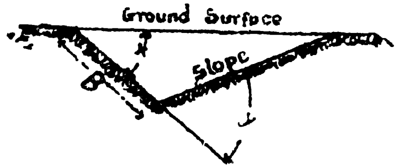
Area of side slope = 185400

Depth.	Area of side slope.	Contents of central portions.	Depth.
0	0	81 × 30 × 100	0 H.
14	294	243000 =	14
17	434		17
20	600		20
15	338		15
10	150		10
5	38		5
0	0		0 *h.*
	1854		81

Total 185400 + 243000 = 428400.

Road skirting side long ground.

B = width of base.
A = area of section.
x = angle of ground with horizon.
Y = angle of slope with horizon.
A = $B^2 \times K$.



Angle of ground x.	Slopes of upwards side, y				
	1 to 4.	1 to 2.	3 to 4.	1 to 1.	3 to 2.
10	·0922	·0967	·1016	·107	·1199
12	·1123	·119	·1265	·1351	·1562
14	·1329	·1424	·1533	·1661	·1992
16	·1543	·1672	·1794	·2008	·2512
18	·1766	·1937	·2145	·2407	·3164
20	·2	·2222	·25	·2857	·4009
22	·2252	·2538	·2907	·3389	·5128
24	·25	·2857	·3342	·4012	·6702
26	·2777	·3225	·3846	·4761	·909
28	·3067	·362	·4421	·5675	1·3123
30	·3373	·4058	·5091	·6830	2·1551
32	·3703	·4545	·5882	·8333	..
34	·4058	·5091	·6830	1·0373	..
36	·444	·5707	·7987	1·3297	..
38	·4854	·641	·9434	1·7857	..
40	·5307	·7225	1·1311	2·6041	..
42	·5807	·8183	1·385	..	..
44	·6364	·9345	1·754	..	..
46	·6983	1·0729	2·315	..	..
48	·7892	1·25	..	..	..
50	·8488	1·475	..	..	..

Slopes :—

Lengths and angles of slopes.

Slope.	Angle with horizon. D.	M.	Length (height taken as 1·00).	Slope.	Angle with horizon. D.	M.	Length (height being 1·00.)
¼ to 1	75	56	1·0307	1½ to 1	33	42	1·802
½ to 1	63	26	1·118	1¾ to 1	29	44	2·016
¾ to 1	53	·8	1·25	2 to 1	26	34	2·236
1 to 1	45	0	1·4142	3 to 1	18	26	3·162
1¼ to 1	38	40	1·6	4 to 1	14	2	·4 124

Table showing method of calculating Earthwork.

No. of station.	Depth at station. D	Mean depth. d	Area of centre portion. Bd	Area of side slopes. sd²	Total. area. Bd + sd²	Distance between stations, l.	Contents = area × Cut-ting.	Contents = area × Em bank-ment,	Remarks
38	3·7	..	..	..	..	..	..	..	B—30′
39	2·8	3·3	99	22	121	100	..	12100	s—2
40	2·9	2·9	87	17	104	100	..	10400	
		{ 1·5	45	5	50	57	..	2850	
44	—2·2	{ —1·1	33	2	35	43	1505	..	
42	—2·8	—2·5	75	13	88	100	8800	..	
43	—4·3	—3·6	108	26	134	100	13400	..	
44	—0·2	—2·3	69	11	80	100	8000	..	
		{ —0·1	3	0	3	25	75	..	
45	2·7	{ 1·4	42	4	46	75	..	3450	
46	3·2	3·0	90	18	108	100	..	10800	
Total carried forward						..	31780	39600	

Rate of earthwork.

If r = initial rate per ‰ c. ft. of ordinary wortk.
L = mean lead in ft.
d = mean lift in ft.

then Rate = $r + {}\cdot005\,(L+10d)$

Example :—Let r = Rs. 3 per ‰ c. ft.
L = 200 ft.
d = 10 ft.

then Rate = $3 + \cdot005\,(200 + 10 \times 10)$.
= 4·5 *i. e.* Rs. 4-8 per ‰ c. ft.

Rules for ascertaining cost of carriage by coolies and carts :—

When any quantity of given weight or cubic contents (W) has to be moved to any distance (D) in feet by a succession of trips of a number of units of conveyance, whose load in lbs. or cubic feet is (w), then the cost of the transport (W) will depend upon :—

(*i*) X or $\frac{W}{w}$

(*ii*) Y or $\frac{T}{M}$

(*iii*) Z or the hire of a unit of conveyance for a working day.

M = the number of minutes in a working day.

T = the time in minutes taken for a unit to make one trip to (D) and back.

t = the time in minutes taken to load and unload a unit.

S = average speed in feet per minute of a unit.

N = the number of such trips made in a working day.

Then (*i*) $T = \frac{2D}{S} + t$

(*ii*) $N = \frac{M}{T} = \frac{M}{\frac{2D}{S} + t}$

(*iii*) $Y = \frac{T}{M} = \frac{\frac{2D}{S} + t}{M}$

Cost of transport $= X \times Y \times Z$.

EXAMPLE 1. — What would be the cost of removing 100 c. ft. to 600 ft. if coolies cost 10 annas a day?

Cost of transport $= X \times Y \times Z$

$$= \frac{100}{\frac{1}{2}} \times \frac{\frac{2 \times 600}{200} + \frac{1}{2}}{500} \times 10$$

$$= 200 \times .013 \times 10$$

$$= 2.6 \times 10$$

= 26 annas.

= One rupee and 10 annas.

EXAMPLE 2.—Find cost of carrying 20,000 bricks 3 miles in a cart hired at Rs. 1-8-0 a day when a cart can carry 200 bricks in a trip at 100 feet in a minute. M = 9 hours and t = 30 minutes.

Cost of transport $= X \times Y \times Z$

$$= \frac{20,000}{200} \times \frac{\frac{2 \times 3 \times 5280}{100} + 30}{9 \times 60} \times 1\tfrac{1}{2}$$

$$= 100 \times 346 \cdot 81540 \times 1\tfrac{1}{2}$$

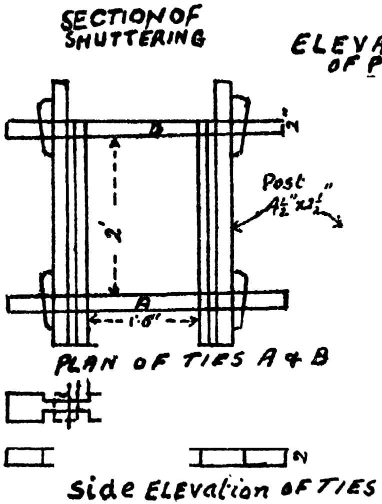
= Rs. 96, 5 annas and 4 pies.

Note.—It will take 65 days for one cart to do the work or 13 carts will do in 5 days but the cost will be a little more. It is better to engage 16 carts for 4 days.

Pise work.

Earth.—The best earth to use should ram well and firmly and not shrink excessively in drying. Pure clay and vegetable soils are unsuitable. Good bri k earth of a sandy clayey nature is best, a small admixture of kankar is useful. The earth should be only just sufficiently wet to ensure its being rolled into big lumps. If the earth is too wet it will shrink and crack.

Shuttering.—The inside of the shutters must be well rammed and kept in gauge. The shuttering consists of wooden frames 10 to 12 ft. long planks, 2½ ft. broad and 2″ thick, held together by tie rods.



Separate set of ties are necessary for different thickness of wall. The holes left by the withdrawal of the tie bars B are filled by sand and cement mortar.

Construction.—A set of shuttering is erected, great care being taken that the sides are vertical and rammed full in 4″ or 5″ layers. The shuttering is then moved about 8 ft. along the wall and the filling and ramming continued. Leave shuttering over night. When working over an old course it is well to set the lower tie rod about 4″ into the same to give the shutters a firm hold on the old work.

SPECIFICATIONS.

Lime Concrete.—

For ordinary foundations the concrete will consist of lime mortar and broken stone or well burnt brick ranging from ½″ to 1½″ in size.

About 33 c. ft. of dry lime is required for each 100 c. ft. of aggregate. About 46 c. ft. of dry mortar (white lime, 1 part and surkhi 2 parts), mixed with 115 c. ft. of stone ballast gives 100 c. ft. of concrete.

Concrete should only be mixed on specially constructed platforms in batches of not more than 25 c. ft. at a time. Ballast should be thoroughly soaked with water before the addition of mortar. Turn over 2 or 3 times adding sufficient water to make a wet, though not too sloppy mixture. Ram thoroughly with 12 lbs. iron rammer until well consolidated.

No lime concrete should be laid for at least an hour before ramming is stopped for the day. All concrete must be rammed in 6 in. layers and all newly laid concrete work must be well watered for 10 days after it has been consolidated.

Lime Concrete over Jack Arching.—

The aggregate shall be broken to $\frac{3}{4}$ in. to $\frac{1}{2}$ in. gauge and the proportion of mortar increased by 10% ; 51 c. ft. of dry mortar=38 c. ft. of wet mortar.

Brick Work.—Burnt Brick in Lime :—

Before laying burnt brick in lime mortar all the bricks must be soaked in water for at least 8 hours. The joints should run all horizontal. Bricks are to be laid with the frogs upwards. No joint or bed shall exceed $\frac{3}{8}$ in. in thickness. Temporary steps, left during construction must be raked back and not toothed.

All buttresses and similar projections are to be built up course by course with the parent wall.

In ordinary brickwork, 33 c. ft. of dry mortar is required per 100 c. ft. of masonry.

Chimneys.—Each fire-place must have a distinct flue to itself, which should never be finished less than 9 in. square, though 14″ × 7″ is a better size. When wood is intended to burn, allow 144 sq. ins. *i. e.*, say 16″ × 9″. A chimney should be of uniform section throughout except over the centre of the fire-place where it should be reduced in area by about 30% to form a throat. When a fire-place projects into a room, the arch should be supported by a chimney bar, $2\frac{1}{2}$″ × $\frac{1}{2}$″ in section, having a bearing of not less than $4\frac{1}{2}$ in. on each jamb.

All chimneys should be carried up with a minimum thickness of $4\frac{1}{2}$ in. to a height of not less than 3 ft. above roof level. Flues should be carefully plastered as the work proceeds. The use of plaster should be avoided round the back and sides of a grate.

Masonry :—Stone masonry will, unless otherwise specified, be of the kind known as coursed rubble masonry. Every stone should be laid on its natural quarry bed. No course shall be less than 5 inches in height nor more than 12 inches and the deeper courses are laid at the bottom of the wall.

All stones must be thoroughly soaked with water before being laid in the works.

No stone should be used which is less than half a cubic foot in size. The bed of each stone must not be less than one and half times its height and at least half the stones should tail into the wall twice their height. Stones must break joint by at least half the height of the course.

Through bond stones will be inserted on each course at five feet intervals.

Dry Rubble Masonry :—

Used for road work in hills. Retaining walls should be built in accordance with the sections shown in Part II. Deep foundations are necessary. The stones will be roughly hammer dressed to secure the largest possible bedding surfaces. Bond stones will be provided in each course at intervals of 5 feet of the greatest length procurable, the minimum being 2 feet weep holes are required. Filling behind walls will consist of refuse or chips. The use of earth should be avoided.

Dhujji Walling :—

It consists of a frame work of timber filled in with masonry or brickwork, plastered on all interval surfaces and plastered or pointed on the outside. Total thickness 6 in. approx. The timber used shall be well seasoned. Damp-proof course is necessary.

Having erected the framework, the vertical and horizontal members are firmly fastened together on both sides of all junctions with ⅜ in. diameter, iron spikes and the diagonal braces secured at their ends to these members with 4 in. wire nails.

The panels are then filled in with masonry or brickwork. Before plastering a wall, after completion of filling the framing should be covered with ½ in. mesh wire netting, nicked, or have nails driven into it to form a key for the plaster.

Lime Pointing.—

Pointing should be done, in the case of burnt brick in lime as the brick work progresses.

In the case of burnt brick in mud, all joints must be raked out to a depth of ¾ in. and the face of the wall well washed down and watered before pointing is commenced. After pointing is finished, it must be kept wet for at least 5 days. Proportion 1 lime and 3 sand by volume.

A superior class of work in conjunction with burnt brick in mud is known as *Jibbi* work, and consists of bedding the face brick to a depth of 2 in. in lime mortar and pointing carried out as in the case of burnt brick in lime.

Lime Plaster :—

The joints should be raked out to a depth of ½ in. to ¾ in., the walls should be cleaned and well wetted before plastering. The plaster should be of pure kankar lime applied in a single coat not exceeding ½ in. Add 4 ozs. of hemp to every 100 sq. ft. of plaster. The plaster should be beaten with thin thapies to ensure good key with the wall and floated with straight edge to given even surface and finally rendered quite smooth, lime putty being added when necessary.

All lime or cement plaster work must be kept wet for 10 days after completion.

Proportion, 1 lime and 2 sand by volume.

Distempering.—

For distempering, the walls shall be prepared and the distemper applied, in accordance with the instructions given by the firm whose distemper is used. Distemper should only be applied in dry weather with a broad stiff brush, and each coat should be quite dry before applying the next.

The following directions apply to Hall's distemper :—

The package must be kept closed. To mix for use about a pint of water should be added to 5 lbs. of distemper. Use hot water if distemper is stiff, walls to be distempered require a preliminary coat of Clairecolle, a mixture of concentrated size or glue with whiting and a little alum.

Floors.—

All floors (except earth) resting on the ground will be provided with a lime concrete foundation laid over a minimum thickness of 4 in. of sand.

Conglomerate Flooring :—

A very successful kind of floor is made of stone pebble, sand and cement all laid *in situ*. The proportions are as follows :—

Stone pebble (clean from river bed) to pass through a mesh of ¼ in. or 16 meshes to the square inch .. .. .. 4 parts.

Sand, coarse gravel, to be perfectly free from clay, and when put in a glass of water, the water should present perfectly transparent appearance .. .. 2 ,,

Portland Cement, best English, fresh .. .. .. 1 part.

The mixture to be laid in squares of say 6′× 3′ or 5′×2½′ the divisions being secured by thin flat bar, iron 2″× ¼″ and immediately rammed and smoothed but not plastered.

The flooring is 2″ thick, laid on ordinarylime concrete—3″ to 6″ thick.

Immediately after the mixture is laid, the iron bars should be slightly shaken so that the mixture can get room to shrink. On the next day the bar should be taken out and the joints to be filled with pure cement and sand (in proportion of 1 to1). The surface to be covered with 3″ of water which should be replenished daily so that the entire floor is under water for not less than a fortnight. This will make a hard, and smooth floor, peculiarly fitted for Hospitals.

The secret of the success of this floor lies in—

(*a*) The purity and freedom of pebble and sand from clay.
(*b*) The quality of cement.
(*c*) The day's work to be finished with a complete slab.
(*d*) Plenty of room for shrinkage.

On no account is the cement concrete surface to be plastered. If a coloured surface is required, it will be obtained by using a suitable colouring matter.

Roofing—Jack Arching.—

The span varies from 4 to 6 ft. with a curvature of 60 degrees and shall consist of single 4½ in. rings, laid on edge with all joints radiating from the centre. The bricks forming the springing course must be specially moulded to fit the joists and laid in cement mortar. The joists will be cased in fine cement concrete with a minimum thickness of 1 in. of concrete over the upper flange and then the haunches will be filled and the arching covered to a depth of 1½ in. over the crown. The end arch of a series of jack arches in a roof springing from an unsupported outer wall will be supported by a 3″× 3″×⅜″ angle iron bedded in the wall and tied to the first joist by ⅝ in. diam-tie rods spaced about 5 ft. apart. • At least 3 complete lines of centerings will always be in use, so that each arch under construction will have the two preceding one still supported on centerings.

Allahabad Tiling.—Roof slope 2 to 1. Tiles must be thoroughly burnt. A dry tile shall not absorb more than ⅙th of its weight when immersed in water for 24 hours. May be single or double.

Mangalore Tiling.—This type of roof should never be pitched at an angle of less than 30°. Each tile covers 12″× 8″, 150 tiles are required for 100 sq. ft. of roofing and weigh 4 tons approx.

QUANTITIES.

1. Excavation in hard rock requiring blasting including removal to a distance of 150 ft. :—

Material for 1000 c. ft.		Labour for 1,000 c. ft.	
Blasting powder	lbs. 30	Excavation, Miners	.. No. 16
Fuse coils	No. 10	Excavation, coolies	.. No. 18
Charcoal	lbs. 50	Removing spoil, coolies	.. No. 4
		Mate	.. No. 2

2. Reinforced concrete 1 : 2 : 4 Aggregate ½ in. broken stone for lintels including reinforcement and forms, etc :—

Material for 100 c. ft.		Labour for 100 c. ft.	
½ in. ballast	c. ft. 88	Mason	. No. ½
Sand	c. ft. 44	Coolies for measuring	. No. 1
Cement	c. ft. 22	Coolies for mixing	. No. 3
Round iron	cwt. 3	Coolies for carrying	. No. 3
		Coolies for ramming	. No. 3
		Bahishti	. No. 1
		Mate	. No. ½

3. Lime Concrete in Foundation pavements.

Material for 100 c. ft.		Labour for 100 c. ft.	
Ballast, 1½ in.	.. c. ft. 110	Mason	.. No. ½
Lime	.. c. ft. 16	Coolies for measuring material	No. 1
Surkhi	.. c. ft. 24	Coolies for mixing	.. No. 3
		Coolies for carrying	.. No. 3
		Coolies for ramming	.. No. 3
		Bahishti	.. No. 1
		Mate	.. No. ½

4. Lime Concrete walls including erection of casing but not its cost, exposed faces to be worked smooth during the progress of the work by the addition of fine material.

Material for 100 c. ft.		Labour for 100 c. ft.	
Lime screened	c. ft. 4	Masons	.. No. 1½
Surkhi screened	c. ft. 6	Coolies	.. No. 14
		Bahishti	.. No. 1
		Mate	.. No. ½

5. Lime concrete walls 1 in. lime stone metal in moulded blocks including plastering on one face: proportion of ingredients 1 : 1½ : 11; including cost of forms.

Material for 100 c. ft.		Labour for 100 c. ft.	
1 in. ballast	.. c. ft. 110	Masons	.. No. 3½
Lime slaked	.. c. ft. 10	Coolies	.. No. 19
Surkhi	.. c. ft. 15	Bahishtis	.. No. 1½
For joints;—Lime screened	.. c. ft. 8	Mate	.. No. 1
Surkhi screened	c. ft. 12		
For plastering:—Lime	.. c. ft. 2		
Surkhi	.. c. ft. 3		

6. 1st Class brick work in lime mortar, arch work.

Material for 100 c. ft.		Labour for 100 c. ft.	
1st class bricks	.. No. 1600	Brick-layers	.. No. 9
Lime	.. c. ft. 16	Coolies	.. No. 6
Surkhi	.. c. ft. 24	Bahishti	.. No. ½
		Mistri	.. No. ⅛

7. Ashlar masonry work in lime mortar all bed joints and faces tooled.

Material for 100 c. ft.		Labour for 100 c. ft.	
Stones not less than 2′× 1′× 1 in. size	.. c. ft. 100	Masons for dressing	.. No. 46
Lime slaked and screened	.. c. ft. 8	Masons for laying	.. No. 4
Sand or surkhi	.. c. ft. 12	Coolies	.. No. 9
Charcoal	.. lbs. 20	Bahishti	.. No. ½
		Blacksmith	.. No. 2
		Bellow-boys	.. No. 2

8. Coursed rubble masonry in lime mortar in superstructure faces chisel-dressed.

Material for 100 c. ft.		Labour for 100 c. ft.	
Bond stones	.. No. 36	Dressing masons	.. No. 8
Quarry stones	.. c. ft. 150	Laying masons	No. 4
Lime slaked	.. c. ft. 12	Coolies	.. No. 8
Surkhi	.. c. ft. 18	Bahishti	.. No. ½
Charcoal	.. lbs. 20	Blacksmith	.. No. 1
Steel	.. lbs. 2	Bellow-boy	.. No. 1

9. 1 in. Portland cement flooring (proportion 1 : 2 : 4) on 3 in. lime concrete :-

Material for 100 s. ft.		Labour for 100 s. ft.	
Lime concrete	.. c. ft. 25	Masons	.. No. 2½
½ in. stone metal	.. c. ft. 7	Coolies	.. No. 4
Sand	.. c. ft. 3½	Bahishti	.. No. ½
Cement	.. c. ft. 1·7		

10. 1st class flat brick flooring on 3" in. lime concrete excluding pointing:—

Material for 100 s. ft.		Labour for 100 s. ft.	
Lime concrete	.. c. ft. 25	Brick-layer	.. No. 1
Bricks	.. No. 350	Coolies	.. No. 2
Lime slaked and screened	.. c. ft. 4	Bahishti	.. No. $\frac{1}{8}$
Surkhi	.. c. ft. 6		

11. 1st class brick-on-edge flooring set in lime over 3 in. lime concrete excluding pointing.

Material for 100 s. ft.		Labour for 100 s. ft.	
Lime concrete	.. c. ft. 25	Brick-layer	No. $\frac{1}{2}$
Bricks	.. No. 470	Coolies	No. 3
Lime screened	.. c. ft. 6	Bahishti	No. $\frac{1}{4}$
Surkhi	.. c. ft. 9		

12. $\frac{1}{2}$ in. lime and surkhi plaster on brickwork.

Material for 100 s. ft.		Labour for 100 s. ft.	
Lime	.. c. ft. $2\frac{1}{2}$	Masons	. No. $1\frac{1}{2}$
Surkhi	.. c. ft. 4	Coolies	. No. $2\frac{1}{2}$
		Bahishti	. No. $\frac{1}{10}$

13. $\frac{1}{2}$ in. Portland cement plaster 1 : 2 on brickwork.

Material for 100 s. ft.		Labour for 100 s. ft.	
Cement	c. ft. 2·3	Coolies	No. $2\frac{1}{2}$
Sand	c. ft. 4·6	Masons	No. $1\frac{1}{2}$
		Bahishti	No. $\frac{1}{16}$

14. Leeping outer walls and roofs.

Material for 100 s. ft.		Labour for 100 s. ft.	
Soft earth	c. ft. 1	Coolies	No. $\frac{1}{2}$
Cow-dung	c. ft. 1·2	Bahishti	No. $\frac{1}{16}$
Sand	c. ft. 0·25		

15. Portland cement pointing 1 : 1 on brick-on-edge floor.

Material for 100 s. ft.		Labour for 100 s. ft.	
Cement	c. ft. $\frac{1}{2}$	Mason	No.
Sand	c. ft. $\frac{1}{2}$	Coolies	No.

16. Lime pointing on brickwork.

Material for 100 sq. ft.		Labour for 100 s. ft.	
Lime mortar	c. ft. $2\frac{1}{2}$	Mason	No. 1
		Coolies	No. 2

17. Dhajji Walling Framework, 5 ins. thick with mud plaster 2 side.

Materials for 100 c. ft.

Item	Unit	Quantity
Deodar wood	c. ft.	10
Nails, etc.	..	..
Stones	c. ft.	40
Sundries		

Labour for 100 c. ft.

Item		No.
Carpenters	..	2
Mason	..	1
Coolies	..	2
Women and boys	..	3
Bahishti	..	$\frac{1}{8}$

18. bricks 9″ × 4½″ × 2¾″

Materials for 1000 Bricks.

Item	Quantity
Fire-wood	14 Mds.

Labour for 1000 Bricks

Item	No.
Moulders	1
Coolies for digging, pugging and carrying earth, etc.	2
Women and boys for carrying and stacking dried bricks	3
Bahishtis	$\frac{1}{3}$
Coolies for loading kiln	1
Women for loading kiln	2
Coolies for firing	1
Coolies for unloading and stacking	1

19. Reinforced brickwork 1 layer of bricks on edge.

Materials for 100 sq. ft.

Item	Unit	Quantity
Rough planks for centering	sq. ft.	120
Bricks or wedges under cross beams	No.	12
Earth and sand for top dressing	c. ft.	16
$\frac{3}{8}$in. round iron bars	cwt.	1
Bricks delivered at site	No.	470
Cement	c. ft.	4½
Sand	,,	13

Labour for 100 sq. ft.

Item	No.
Masons for preparing centering	
Carpenters for preparing centering	1
Masons for laying	3
Masons for removing centering, patching up voids, making good damage to walls, etc.	$\frac{1}{4}$
Coolies to help in above	14
Blacksmith	1
Bahishti	1
Mistri	1

USEFUL RECIPES.

Protecting wood from white ants :—

(i)

Arsenic	.. 1 seer.
Country soap	.. 4 seers.
Corrosive sublimate	.. $\frac{1}{2}$ seer.
Turpentine	.. 4 seers.
Water	.. 20 seers.

Grind fine arsenic and corrosive sublimate. Mix with the remaining articles and boil for 4 hours. Cool and it is ready for use. If thick mix more water. Apply with brush. Corrosive sublimate is an effectual poison to them.

(ii) Copper sulphate one seer and water 10 seers. Mix well. Dip the required piece of wood from 4 to 8 days.

Repairing Cracks in Terraced Roof :—

(1)

Linseed oil	.. 2 seers.
Rosin	.. 2 ,,
Pumice stone or fine sand	.. 1 seer.

Boil the oil and mix the rosin well and then mix the pumice stone. Fill the cracks with this mixture while hot and smooth over surface.

(2)

Linseed oil	.. $\frac{1}{2}$ seer.
Rosin	.. 5 seers.
Pumice stone or fine sand	.. $\frac{3}{4}$ seer.

Heat the rosin in an iron pot and mix with oil. When the rosin is melted, mix the powdered Pumice stone or fine sand. Apply to cracks when hot.

Note.—Stretch a piece of cord $\frac{1}{4}$ in. thick on all the four sides of cracks leaving 2 in. space so that the mixture may not spread on the whole roof.

(3) In case the cracks are big, use the following ;—

Asphalt	.. 20 seers.
Coal-tar	.. $1\frac{1}{2}$ seer.
Sand	.. 5 seers.

Boil all together. Clean the cracks and fill the cracks with the mixture.

(4) To fill in fine hair cracks in new roofs. Mix cement, cow dung and sand in equal proportions and spread on roofs in thin condition. It will take 2 days to set.

Recipe for Colouring Bricks or Tiles :—

(1) For Dark Red Bricks.

Turpentine	$1\frac{1}{2}$ pt.
Linseed oil	$1\frac{1}{2}$ pt.
Litharge	$\frac{1}{4}$ oz.
Indian Red	$\frac{1}{2}$ oz.

(2) For Blue Bricks.

Turpentine	.. 1 pt.
Linseed oil	.. 1 pt.
Litharge	.. $\frac{1}{2}$ oz.
French ultramarine	.. 1 lb.

(3) For Black Bricks.

Litharge	2 ozs.
Manganese	6 ozs.
Linseed oil (boiled)	4 ozs.
Turpentine	6 ozs.

(4) For Grey Bricks.

White lead	.. 8 ozs.
Litharge	.. 1 oz.
Manganese	.. 1 oz.
Linseed oil (boiled)	.. 2 ozs.
Turpentine	.. 4 ..

Mix well together and use as under :—

Pour half the mixture in a vessel in which the brick can be dipped easily. Heat the bricks one by one and dip in the solution, then dry.

China Cement :—To three parts of fresh beaten blood are added 6 parts of slaked lime and a little alum, a thin pasty mass is produced which can be used immediately. Objects which are to be made especially waterproof are painted by the chinese twice or at the most three times.

Cements for Glass.—From 5 to 10 parts of pure dry gelatine are dissolved in 100 parts of water. To the solution about 10% of a concentrated solution of bichromate of potash is added and the liquid is kept in the dark. When articles joined with this cement are exposed to the light, the gelatine film is acted upon by the chemical rays, the chromate being partially reduced and the film of the cement becomes tough and durable.

Glass Cement.—Take pulverized glass 10 parts, powdered fluor-spar 20 parts, soluble silicate of soda, 60 parts. Both glass and the fluor spar must be in the finest possible condition which is best done by shaking each in fine powder, with water allowing the coarser particles to deposit and then to pour off the remainder which holds the finest particles in suspension. The mixture should be made very rapidly, by quick stirring and when thoroughly mixed, must be at once applied. This is said to yield an excellent cement.

To preserve Wooden Labels.—First dip in strong solution of iron sulphate. Dry and dip it again in lime water. The sulphate of lime is deposited on the surface of wood for ever.

To write on Zinc.—Write with a pen dipped in blue vitrol, *i.e.*, sulphate of copper.

Water proof Mixture :—

Tallow	.. 5%	Gutta Percha	.. 20%
Resin	.. 15%	Pitch	.. 60%

Oil Cement for laying earthen pipes :—

Dry slacked lime	.. 5 lbs..
Oil (by weight)	.. 1 lb.

☞ Pounded in stone mortar with iron pestle for 6 hours, to reduce it to a thick paste for use.

To remove paint from wood :—

2 lbs. of caustic soda to one gallon of water will remove one coat of paint in one or two minutes. If left too long on wood-work, it does harm and will shorten the life of the timber.

Whiting	.. 1 seer.
White lead (dry)	.. 1 chhatak.
Raw linseed oil	.. 6 chhataks.
Litharge	.. 2½ tolas.

Mix well together and beat with a wooden mallet. If it becomes hard, heat it before application.

Fluxes for Soldering or Welding.

Metals.		Soldering materials.
Iron or steel	..	Borax or Sal ammoniac.
Tinned iron	..	Resin or chloride of zinc.
Copper	..	Sal ammoniac or chloride of zinc.
Brass	..	Sal ammoniac or chloride of zinc.
Zinc	..	Chloride of zinc.
Lead	..	Tallow or Resin.
Lead and tin pipes	..	Resin and sweet oil.

Recipe for Patent Knotting:—

Japanner's gold size	..	¼ pint.
Red lead	..	1 tea-spoonful.
Wood naphtha	..	1 pint.
Orange shellac	..	7 oz.

Add together and keep the mixture in a warm place, whilst the shellac is dissolving, to be shaken frequently.

Efflorescence on Brickwork.—This white coating, which is such a disfigurement, can usually be prevented by adding oil to the mortar at the rate of 1 gallon to the cask of lime. Linseed oil or any oil not saline, will do. If cement is used, an extra gallon of oil must be added. When incrustations are once formed, nothing can be done except to wash with dilute hydrochloric acid.

Testing Drains and Pipes:—

Ignite soiled cotton waste and sulphur and blow the smoke into the drain or pipe. If the leakage exists in the latter inside of the house, the smell and the smoke both issue forth and indicate the position of the fault. Sulphur is one of the best disinfectants and a dose of the fumes from this to the drains, after disease has been in the house would effect much good.

To remove Ink Spots on Floors.—Rub with sand wet with equal parts of water and oil of vitriol, when ink is removed rinse with weak lye water.

To remove Oil Stains from floor.—Use oxalic acid and water, then wash well with soda and soap.

Wall Paper.—To remove all stains or marks (where people have rested their hands) from wall papers, mix pipe clay with water to the consistency of cream, lay it on the spot and allow it to remain till the following day when it may easily be removed with a brush.

How to make Frosted Glass.—Take an empty 1 lb. jar pot or any similar vessel and fill it $\frac{1}{3}$rd full with gum-arabic. Add a little hot water and leave it to soak for some hours. When the gum is properly dissolved add the same quantity of epsom salts. Stand the jar in a basin of hot water and stir rapidly. Then apply the contents to the glass with a paint brush. The mixture gives a permanent frosted effect. The light will enter freely but it will not be possible to see through it.

To clean Zinc.—Mix 1 part of sulphuric acid with 12 parts of water. Dip the zinc into it for a few seconds then rub with a cloth.

To clean Ivory.—(1) Expose the ivory for 3 or 4 days to the action of sunlight in a bath of turpentine oil. (2) Treat it alternately with a solution of potassium permanganate (1 : 250) and oxalic acid (1 : 100), letting the ivory remain in each solution for half an hour; then rinse well with water and repeat the process a number of times.

Colouring of Concrete.—For the colouring of moulded concrete, the colouring matters, in proportions depending upon the required shade, should be thoroughly mixed with the dry Portland cement before it is added to the aggregate. The following are suitable proportions:—

Red.

Parts.	
87	Fine-ground Portland cement.
11	Red oxide of iron.
2	Black oxide of iron or copper.
100	

Yellow.

Parts.	
84	Fine-ground Portland cement.
14	Yellow oxide of iron.
2	Black oxide of iron or copper.
100	

Blue.

Parts.	
80	Fine-ground Portland cement.
18	Azure blue or ultramarine.
2	Black oxide of iron or copper.
100	

Green.

Parts.	
85	Fine-ground Portland cement.
12	Oxide of chromium.
3	Black oxide of iron or copper.
100	

Chocolate.

Parts.	
88	Fine-ground Portland cement.
6	Black oxide of manganese.
4	Red oxide of iron.
2	Black oxide of iron or copper.
100	

Pink.

Parts.	
84	Fine-ground Portland cement.
15	Barium sulphate (c. barytes).
1	Best quality crimson lake (alumina base).
100	

Black.

Parts.	
87	Fine-ground Portland cement.
13	Black oxide of manganese or any carbon black.
100	

White.

Parts.	
67	Fine-ground Portland cement.
33	Powdered chalk or barium sulphate (common barytes).
100	

Cleaning Marble.—Mix one part by weight of country soap and 3 parts of quick lime in sufficient water to form a paste. Lay on with a brush and, when dry, rub down with pumice stone.

Another method is to pass through a fine screen (so as to eliminate all particles capable of scratching the marble) two parts bicarbonate of soda, one part powdered pumice stone, and one part of finely pulverized chalk and then add sufficient water to form a pasty mass. The marble should be rubbed with this mixture and finally washed with soap and water.

To remove Spots from Clothing.—Rub spots with Petrol, Benzoin or Ether. Use a circular movement, rub until dry around the edges.

To take out Ink.—If fresh, soak and wash spots in milk. If not fresh, apply oxalic acid and water, one tea-spoonful of the acid in ½ tea-cupful of water. Wash out immediately.

To remove Paint.—Use turpentine. If the paint is dry and the garment can be washed, soak the spot in turpentine over night and wash in water with soap. Otherwise put some turpentine on spot and let stand a while before rubbing.

To take out mildew from White Articles.—Dissolve 1½ ozs. of chloride of lime in one quart of boiling water strain. Wet articles first in water then soak in solution for several hours. Rinse in cold water.

For Rust Stains.—Apply lemon juice and salt and lay on the grass, if possible, in the sun. Wash out afterwards.

For Scorched Linen or Cotton.—Take one large onion, vinegar, soap and Fuller's earth. Use 4 times as much vinegar as soap and Fuller's earth. Put on fire and bring to boil. Spread thickly on spots and let dry. Wash well in warm soap suds.

To clean White Kid Gloves.—Clean on the hands with petrol, benzoin or carbona. The latter is the best. After cleaning hang out in the air.

To clean Wall Paper.—The best thing is stale bread, keeping strokes all in the same direction.

Data for Blasting 100 c. ft. of Rock.—1 lb. of dynamite, 7 running ft. of boring, ½ coolies, 6 running ft. of fuse, 3½ detonators. In small blasts 1 lb. of powder will loosen about 4½ tons. In large blasts 1 lb. of powder will loosen about 2¾ tons. One man can bore 50 to 100 inches per day in granite and 300 to 400 inches per day in limestone.

To *freshen and clean Carpets and Rugs.*—Sponge with hot water in which has been added some domestic ammonia.

To clean Brass.—Mix bath brick dust, whitening and paraffin oil to a paste and apply with a flannel cloth, rubbing vigorously. Rub off with another flannel and polish with a chamois.

To clean Silver.—Use any kind of good silver polish or whitening and liquid ammonia mixed to a paste.

To remove White Spots from Furniture.—Rub olive oil over spot, then fine salt. Then polish with dry flannel or chamois.

To clean lace which is fine and will not stand washing, cover with powdered magnesia, put between pieces of heavy white paper and put away for a couple of days then brush out.

To remove Tea Stains.—Use bleaching soda or lemon and salt.

FERRO TYPE AND OTHER PRINTING PROCESSES.

1. Ferro-type printing (White lines on blue ground):—

The paper for printing can be obtained already sensitised, but in India this is not recommended as sensitised paper deteriorates very rapidly. Much better results can be obtained with freshly sensitised paper.

Method of sensitising paper:—

Two solutions are prepared.

(1)	Citrate of iron and ammonia	.. 100 grains.
	Distilled or rain water	.. 1 oz.
(2)	Ferric Cyanide of Potassuim	.. 70 grains.
	(Red Prussiate of Potash)	
	Distilled or rain water	.. 1 oz.

These two solutions should be kept in blue coloured bottles and stored in a dark room. Mix equal parts of the two solutions in a dark room immediately before use and coat the paper with a sponge or cloth. The coating should be done twice crossways, taking care that no streaks are visible. The paper should be pinned to the drawing board during the operation and afterwards hung up in the dark to dry.

The sensitised paper should be placed under the cloth tracing to be printed in a wooden printing frame. The exposure will vary according to the light, which may be taken as about 5 minutes in the clear sun to about half an hour in cloudy weather.

After exposure the print should be taken out in a subdued light, and washed for about 5 minutes in at least two changes of cold water till the whites are clear, and then hung up to dry. If the blue colour is faint and appears to wash out, it is a sign that the print is under-exposed. If the whites are not clear, the print has been over-exposed or the paper is bad.

An addition of small quantity to Gum Arabic or Dextine one oz. and Potassium Bichromate 2 grains to the above solution will improve the paper.

White lines may be obliterated from the print with a solution of Prussian blue mixed to the required tint.

Any additions to whites may be made with a clear pin dipped in a solution of soda or the following solution :—

Oxalate of Potash	.. 150 grains.
Saturated solution of gum	.. 40 minim.
Water	.. 1 oz.

Both these solutions eat away the blue colour, the print should be blotted after the additions come up white and clear, and then washed.

Additions can also be made to the print with white ink which should be applied as dry as possible.

White lines on a brown ground.—The following solutions are necessary:—

Sensitising solution —

(1)	Silver Nitrate Re-crystallized	.. 5½ drams.
	Distilled or boiled water	.. 4 to 5 oz.
(2)	Citric acid crystals	.. 10 drams.
	Iron and ammonia Citrate dry (brown)	.. 20 drams.
	Distilled or boiled water	.. 4 to 5 oz.

5 ozs. of water should be used in hot weather and 4 ozs. in damp weather for both solutions.

Clearing Solution.—

(*a*) Alum Crystals	1 oz.
Water	40 ozs.
(*b*) Hyposulphite of Soda	1 oz.
Water	16 to 20 ozs.

(20 ozs. of water should be used in hot weather and 16 ozs. in cold damp weather.)

Better results are obtained if the paper is slightly warmed before the sensitising solution is applied.

After exposure the prints should be thoroughly washed and then placed in a bath of the clearing solution for about a minute. Then again washed and placed for about 20 minutes in a bath of the fixing solution. After this process, they should be finally washed and hung up to dry, great care should be taken, otherwise the print will fade rapidly.

II.—Positive Cyanotype Process (blue lines on white ground.)

In this process a print has to be obtained as described for a white line on brown ground but special ready made thin paper must be used. In case ready made paper is not available, prepare as follows :—

	Gum Arabic	.. 1 oz.
	Water	.. 5 ozs.
B	Ammonia citrate of iron	.. 1 oz.
	Water	.. 2 ozs.
	Perchloride of iron	.. 1 oz.
	Water	.. 2 ozs.

When required mix solution No. A, 20 parts with B, 8 parts and No. C, 5 parts. This print is then used as a negative and a blue print made in exactly the same way as if a print was being taken from a cloth tracing.

III.—Ferro-gallic Printing Process (black lines on clear ground of drawing).

Sensitising solution—

Water	15 ozs.
Gelatine	½ oz.
Perchloride of iron	1 oz.
Tartaric acid	½ oz.
Persulphate of zinc	½ oz.

Time of printing varies from 5 to 10 minutes.

Developing Solution.—

Gallic acid	1 oz.
Oxalic acid	5 grains.
Methylated spirit	10 ozs.
Water	50 ozs.

The paper should be on the above solution till black lines are visible on white ground and then washed in water and hung to dry. The process should be performed in yellow light.

For ready made paper use the following Developing Solution.—

Gallic acid	.. 1 oz.
Alum	.. 1 oz.
Water	.. 8 pints.

Dissolve alum and acid in 2 pints of water and then add the remaining water.

IRRIGATION.

Terms and Definitions :—

***Abiana.*—The occupiers rate charged for the supply of canal water.**

Aqueduct.—A channel for conveying water either above or below ground, but on canals the term is confined to the structure spanning a river or other waterway and carrying the canal over it.

Bi-furcation.—A structure in a channel including a regulator where supplies are divided up into two channels leading off in different directions.

Canal, perennial.—A canal that derives its supply from a site on a river where water is available or can be made available throughout the year and provided with head regulator for the control of its supply.

Canal, inundation.—A canal that derives its supply from a river under circumstances that do not permit of the available supplies being kept under control. Inundation canals are, therefore, only run in the summer season when the river levels are sufficiently high.

Cusec.—Cubic feet per second.

Delta. = Very often expressed by Δ

$$= \frac{2 \times \text{average supply} \times \text{No. of days canal is in flow}}{\text{area irrigated.}}$$

Fall.—The works by which the bed is let down from a higher to a lower level.

Foot acre.—One cusec running continuously for 24 hours represents a volume of 86,400 c.ft. This is sufficient to irrigate one acre (area 43,560 s.ft.) to a depth of nearly 2 ft. Foot acre, therefore, represents ½ cusec running continuously for 24 hours. Therefore.

43,200 c.ft. = one foot-acre.

Inlet.—A passage whereby the drainage water intercepted by the canal line is allowed to pass into it.

Irrigation.—The artificial process of supplying water to crops in countries where the rainfall is either insufficient or comes at the wrong season for their cultivation.

Khadir.—The strip of low land within which a river meanders and over which its floods rise.

Kharif.—The season from February 15th to October 14th. Official dates are 1st April to 30th September.

Module.—A device made to ensure a constant discharge from one channel to another irrespective of levels in each within specified limits.

Level crossing.—A work constructed so as to pass the flood water of a torrent or river through the canal on the canal bed level.

Out-lets are required in connection with inlets when there is no escape lower down the canal suitable for removing the inlet drainage water.

Rabi.—The season from 15th October to 14th February. Official dates are 1st October to 31st March.

Rapids are employed to accomplish the necessary change of level in the canals bed instead of falls.

Regulators are simple structures consisting of a floor supported on a concrete foundation with piers grooved to hold the planks required for temporarily raising the water surface level.

Seepage is a term generally used to imply the action which occurs when water soaks or sinks into the ground and is largely retained in it by passing slowly through the mass of soil. It also denotes the action which goes on when water which has been so absorbed by the soil is slowly given up again into any channel or depression which lies at a lower level than the water table in the saturated soil.

Superpassage affords the only possible means of dealing with torrents when they are carrying hill detritus in large quantities.

Under Sluices are openings in a weir, to keep the canal head free from river silt, as a help to the training of both the flood and cold weather supplies of the river and for minor regulation of supplies to avoid the necessity of frequently raising and lowering the weir shutters.

Weirs (*main*) consist of permanent bars across the river high enough to turn the maximum supply down the canal but allowing of the passage of water over them.

Abbreviations:—

F. S. L.	Full supply level.
H. F. L.	High flood level.
L. F. L.	Low flood level.
L. W. L.	Low water level
D. S.	Downstream.
U. S.	Upstream.
R. L.	Reduced level.

RAINFALL.

1 inch of run-off in a year = ·0736 cusecs per square mile.

1 inch of run-off in an hour = 645 cusecs per square mile = 1 cusec or 22,622 gallons per acre.

1 cusec per square mile = 13·56 inches yearly run off = 31·54 million c.ft. yearly.

100,000 cft. storage per acre = 27·5 inches depth on 1 acre.

100,000 Imperial gallons per acre = 4·4 inches depth on 1 acre.

1,000. gallons per acre per day = 16·08 inches yearly run-off.

Table Showing Rain fall in different Provinces of India.

Locality.	Average Annual Rain-fall in inches.	Locality.	Average Annual Rain-fall in inches.
Orissa	59	Ajmere and Marwar ..	20
Chhota Nagpore	54	Central Provinces ..	51
Central Bengal	56	Madras South	31
Behar	48	Mysore	34
United Provinces	43	Berar	35
Punjab South East ..	23	Gujrat	44
Punjab Central	12	Hyderabad	30
Punjab West	10	Deccan	25

On an average about $\frac{3}{5}$th of rainfall is available for storage. 10% is lost from overflow of storm water.

Heavy station rainfall in India as given by Kemp is :—

Bombay Presidency (West Coast).. .. ..8 inches in 2 hours.
Bombay Town.. .. ..7 to 9 inches in 24 hours.
Central Provinces (Talgaon).. .. .. 7·75 inches in 6 hours.
Sholapur ....10 inches in 7 hours.
Madras Presidency (South Arcot)..7, 8, 9 and upto 11·3 inches in 24 hours.

Greatest rainfall recorded in 24 hours :—

Punjab.	Hoshiarpur ..	14·0	inches.
United Provinces.	Danipur ..	30·4	„
East Bengal and Assam.	Chirapunjee..	40·8	„
Rajputana.	Abu ..	13·0	„
Central Provinces.	Chikalda ..	17·0	„
Bombay.	Roha ..	24·8	„
Madras.	Town ..	20·6	„

Table Showing Rain-falls and Estimated Runs-off for Nagpur.

Monsoon Rainfall in inches.		1"	5"	10"	20"	30"	40"	50"	60"
Runs-off in millions of cubic feet per. square mile.	Good Catchment.	0·002	0·116	0·999	6·970	18·33	34·85	56·69	83·63
	Aver. Catchment.	0·001	0·087	0·749	5·227	13·75	26·13	42·51	62·73
	Bad Catchment	0·001	0·058	0·499	3·485	9·17	17·42	28·34	41·87

Strange's "Storage Reservoirs."

FLOOD DISCHARGES AND RUNS-OFF.

The following formulæ are used in calculating flood discharges of rivers, and, in some cases, are also employed for quite small catchments:—

Ryve's Formula :—$Q = C.M$

Where Q = discharge in cubic feet per second; M = area in square miles, C is co-efficient usually ranging from 450 to 1,000 according to the nature and situation of the catchment. Rainfall data are also taken into consideration by comparisons with established results. This formula is largely used in Southern India.

Dicken's Formula :—$Q = 825M^{\frac{3}{4}}$.

This is the form in which the equation is usually presented, but it is doubtless advisable to vary the co-efficient as in the case of Ryve's formula. The Dicken's formula is probably more particularly suited to the conditions of Bengal and other parts of Northern India. Both these formulæ may be usefully employed in other countries as well.

Table of Values of $M^{\frac{2}{3}}$ applicable in Ryve's Formula.

M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$	M	$M^{\frac{2}{3}}$
1	1·000	19	7·12	46	12·84	73	17·47	100	21·54	270	..	750	..	1450	..
1·5	1·310	20	7·37	47	13·02	74	17·63	105	..	280		775		..	..
2·0	1·587	21	7·61	48	13·21	75	17·78	110	22·97	290	..	800	..	1500	..
2·5	1·842	22	7·85	49	13·39	76	17·94	115	..	300	..	825	..	..	..
3·0	2·080	23	8·09	50	13·57	77	18·10	120	24·33	310	..	850	..	1550	..
3·5	2·305	24	8·32	51	13·75	78	18·26	125	..	320	..	875	..	..	..
4·0	2·519	25	8·55	52	13·93	79	18·41	130	25·90	330	..	900	..	1600	..
4·5	2·726	26	8·77	53	14·11	80	18·57	135	..	340	..	925	..	..	..
5·0	2·924	27	9·00	54	14·29	81	18·72	140	26·93	350	..	950	..	1650	..
5·5	3·116	28	9·22	55	14·46	82	18·87	145	..	360	..	975	..	..	..
6·0	3·302	29	9·44	56	14·64	83	19·03	150	28·23	370	..	1000	..	1700	..
6·5	3·483	30	9·65	57	14·81	84	19·18	155	..	380	..	..	..	..	..
7·0	3·659	31	9·87	58	14·98	85	19·33	160	30·22	390	..	1050	..	1750	..
7·5	3·832	32	10·08	59	15·15	86	19·48	165	..	400	..	..	..	..	..
8·0	4·000	33	10·29	60	15·33	87	19·63	170	..	425	..	1100	..	1800	..
8·5	4·165	34	10·49	61	15·50	88	19·78	175	..	450	..	..	..	..	..
9·0	4·326	35	10·70	62	15·66	89	19·93	180	31·88	475	..	1150	..	1850	..
9·5	4·486	36	10·90	63	15·83	90	20·08	185	..	500	..	..	..	..	..
10	4·642	37	11·10	64	16·00	91	20·23	190	..	525	..	1200	..	1900	..
11	4·95	38	11·30	65	16·17	92	20·38	195	..	550	..	..	..	..	..
12	5·24	39	11·50	66	16·33	93	20·53	200	34·20	575	..	1250		1950	..
13	5·53	40	11·70	67	15·50	94	20·67	210	..	600	..	..	..	..	..
14	5·81	41	11·89	68	16·66	95	20·82	220	..	625	..	1300	..	2000	..
15	6·08	42	12·08	69	16·82	96	20·97	230	..	650	..	..	..	..	..
16	6·35	43	12·27	70	16·98	97	21·11	240	..	675	..	1350	..	..	..
17	6·61	44	12·46	71	17·15	98	21·26	250	..	700	..	..	..	..	..
18	6·87	45	12·65	72	17·31	99	21·40	260	..	725	..	1400	..	..	..

Table of Values of $M^{\frac{3}{4}}$ applicable in Dicken's Formula.

M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$	M	$M^{\frac{3}{4}}$
1	1·0	19	9·1	46	17·6	73	24·97	100	31·62	270	66·61	750	143·3	1450	234·8
1·5	1·36	20	9·46	47	17·95	74	25·23	105	32·8	280	68·45	775	146·9	..	..
2·0	1·68	21	9·81	48	18·23	75	25·48	110	33·97	290	70·27	800	150·4	1500	241·0
2·5	1·99	22	10·16	49	18·52	76	25·74	115	35·12	300	72·08	825	153·9	..	..
3·0	2·28	23	10·5	50	18·8	77	25·99	120	36·26	310	73·87	850	156·0	1550	247·0
3·5	2·56	24	10·84	51	19·09	78	26·25	125	37·38	320	75·65	875	160·7	..	..
4·0	2·83	25	11·18	52	19·37	79	26·49	130	38·5	330	77·42	900	164·1	1600	253·0
4·5	3·09	26	11·51	53	19·65	80	26·75	135	39·6	340	79·17	925	167·5	..	..
5·0	3·34	27	11·84	54	19·92	81	27·0	140	40·7	350	80·92	950	171·1	1650	259·0
5·5	3·59	28	12·17	55	20·20	82	27·24	145	41·79	360	82·64	975	174·6	..	..
6·0	3·82	29	12·50	56	20·47	83	27·49	150	42·86	370	84·35	1000	177·9	1700	265·0
6·5	4·07	30	12·82	57	20·74	84	27·74	155	43·92	380	86·06	..	..	..	..
7·0	4·30	31	13·14	58	21·00	85	27·99	160	44·99	390	87·76	1050	184·5	1750	270·6
7·5	4·53	32	13·46	59	21·29	86	28·24	165	45·82	400	89·44	..	..	..	..
8·0	4·76	33	13·78	60	21·56	87	28·48	170	47·08	425	93·60	1100	191·0	1800	276·0
8·5	4·97	34	14·07	61	21·82	88	28·56	175	48·09	450	97·7	..	..	..	..
9·0	5·20	35	14·40	62	22·09	89	28·98	180	49·14	475	101·75	1150	197·4	1850	282·0
9·5	5·41	36	14·69	63	22·36	90	29·22	185	50·12	500	105·74	..	..	..	..
10	5·62	37	15·00	64	22·64	91	29·46	190	51·18	525	109·7	1200	203·8	1900	287·8
11	6·04	38	15·39	65	22·89	92	29·70	195	52·12	550	113·60	..	..	..	..
12	6·45	39	15·6	66	23·15	93	29·94	200	53·18	575	117·43	1250	210·1	1950	293·2
13	6·85	40	15·9	67	23·40	94	30·18	210	55·16	600	121·23	..	..	..	..
14	7·24	41	16·2	68	23·69	95	30·43	220	57·12	625	125·0	1300	216·1	2000	298·6
15	7·62	42	16·49	69	23·94	96	30·66	230	59·06	650	128·6	..	..	..	..
16	8·00	43	16·79	70	24·20	97	30·91	240	60·98	675	132·5	1350	222·5	..	..
17	8·37	44	17·08	71	24·45	98	31·14	250	62·87	700	136·2	..	..	..	..
18	8·74	45	17·37	72	24·71	99	31·38	260	64·75	725	139·7	1400	228·6	..	..

**Table of Waste-weir Run-offs.*

1	2	3	4	5	
Increments of catchment area.	Run-off from each increment of catchment area in Col. 1.	Discharge from each increment of catchment area in Col. 1 due to run-off.	Discharge from total catchment area due to Run-off.	Average run-off from total catchment area.	REMARKS.
Square miles.	Inches per hour.	Cubic feet per second.	Cubic feet per second.	Inches per hour.	
0 to 1	3·00	1,936	1,936	3·00	
1—2	2·65	1,710	3,646	2·83	
2—3	2·30	1,484	5,130	2·65	
3—4	2·00	1,291	6,421	2·49	
4—5	1·85	1,194	7,615	2·36	
5—6	1·72	1,110	8,725	2·25	
6—7	1·62	1,045	9,770	2·16	
7—8	1·52	981	10,751	2·08	
8—9	1·45	936	11,687	2·01	
9—10	1·40	903	12,590	1·95	
10—15	1·16	3,743	16,333	1·69	
15—20	1·00	3,227	19,560	1·51	
20—25	0·92	2,968	22,528	1·40	
25—50	0·80	12,907	35,435	1·10	
50—75	0·75	12,100	47,535	0·98	
75—100	0·70	11,293	58,828	0·91	
100—150	0·65	20,973	79,801	0·82	
150—200	0·60	19,360	99,161	0·77	

Column 3 = Increment of area in Col. 1 × Col. 2 × 645·33 c.ft.
Column 4 = Sum of entries in Col. 3.
Column 5 = Col. 4 ÷ (Last figure in Col. 1 × 645·33).

*Strange's "Storage Reservoirs."

Total monsoon rainfall in inches.	GOOD CATCHMENT.			AVERAGE CATCHMENT.			BAD CATCHMENT.		
	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.
1	0·1	0·001	0·002	0·1	0·001	0·001	0·05	0·0005	0·001
2	0·2	0·004	0·009	0·15	0·003	0·006	0·1	0·002	0·004
3	0·4	0·012	0·028	0·30	0·009	0·021	0·2	0·006	0·014
4	0·7	0·028	0·065	0·5	0·021	0·048	0·3	0·014	0·032
5	1·0	0·050	0·116	0·7	0·037	0·087	0·5	0·025	0·058
6	1·5	0·090	0·209	1·1	0·067	0·156	0·7	0·045	0·104
7	2·1	0·147	0·341	1·5	0·110	0·255	1·0	0·073	0·170
8	2·8	0·224	0·520	2·1	0·168	0·390	1·4	0·112	0·260
9	3·5	0·315	0·732	2·6	0·236	0·549	1·7	0·157	0·366
10	4·3	0·430	0·999	3·2	0·322	0·749	2·1	0·215	0·499
11	5·2	0·572	1·329	3·9	0·429	0·996	2·6	0·286	0·664
12	6·2	0·744	1·728	4·6	0·558	1·296	3·1	0·372	0·864
13	7·2	0·936	2·174	5·4	0·702	1·630	3·6	0·468	1·087
14	8·3	1·162	2·699	6·2	0·871	2·024	4·1	0·581	1·349
15	9·4	1·410	3·276	7·0	1·057	2·457	4·7	0·705	1·638
16	10·5	1·680	3·903	7·8	1·260	2·927	5·2	0·840	1·951
17	11·6	1·972	4·581	8·7	1·479	3·435	5·8	0·986	2·290
18	12·8	2·304	5·353	9·6	1·728	4·014	6·4	1·152	2·676
19	13·9	2·641	6·135	10·4	1·980	4·601	6·9	1·320	3·067
20	15·0	3·000	6·970	11·25	2·250	5·227	7·5	1·500	3·485
21	16·1	3·381	7·858	12·0	2·535	5·891	8·0	1·690	3·927
22	17·3	3·806	8·842	12·9	2·854	6·631	8·6	1·903	4·421
23	18·4	4·232	9·832	13·8	3·174	7·374	9·2	2·116	4·916
24	19·5	4·680	10·873	14·6	3·510	8·154	9·7	2·340	5·436
25	20·6	5·150	11·964	15·4	3·862	8·973	10·3	2·575	5·982
26	21·8	5·668	13·168	16·3	4·251	9·876	10·9	2·834	6·584
27	22.9	6·183	14·364	17·1	4·637	10·773	11·4	3·091	7·182
28	24·0	6·720	15·612	18·0	5·040	11·709	12·0	3·360	7·806
29	25.1	7·279	16·911	18·8	5·459	12·683	12·5	3·639	8·455
30	26·3	7·890	18·330	19·7	5·917	13·747	13·1	3·945	9·165

Total monsoon rainfall in inches.	Good Catchment.			Average Catchment.			Bad Catchment.		
	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.	Percentage of run-off to rainfall.	Depth of run-off due to rainfall in inches.	Yield of run-off from catchment per sq. mile in Mill. c. ft.
31	27·4	8·494	19·733	20·5	6·370	14·799	13·7	4·247	9·866
32	28·5	9·120	21·188	21·3	6·840	15·891	14·2	4·560	10·594
33	29·6	9·768	22·693	22·2	7·326	17·019	14·8	4·884	11·346
34	30·8	10·472	24·329	23·1	7·854	18·246	15·4	5·236	12·164
35	31·9	11·165	25·939	23·9	8·337	19·454	15·9	5·582	12·969
36	33·0	11·880	27·600	24·7	8·910	20·700	16·5	5·940	13·800
37	34·1	12·617	29·312	25·5	9·462	21·984	17·0	6·308	14·656
38	35·3	13·414	31·163	26·4	10·060	23·372	17·6	6·707	15·581
39	36·4	14·196	32·980	27·3	10·647	24·735	18·2	7·098	16·490
40	37·5	15·000	34·848	28·1	11·250	26·136	18·7	7·500	17·424
41	38·6	15·826	36·767	28·9	11·869	27·575	19·3	7·913	18·383
42	39·8	16·716	38·835	29·8	12·537	29·126	19·9	8·358	19·417
43	40·9	17·587	40·858	30·6	13·190	30·643	20·4	8·793	20·429
44	42·0	18·480	42·933	31·5	13·860	32·199	21·0	9·240	21·466
45	43·0	19·395	45·058	32·3	14·546	33·793	21·5	9·697	22·529
46	44·3	20·378	47·342	33·2	15·283	35·506	22·1	10·189	23·671
47	45·4	21·338	49·572	34·0	16·003	37·179	22·7	10·669	24·784
48	46·5	22·320	51·854	34·8	16·740	38·890	23·2	11·160	25·927
49	47·6	23·324	54·186	35·7	17·493	40·639	23·8	11·662	27·093
50	48·8	24·400	56·686	36·6	18·300	42·514	24·4	12·200	28·343
51	49·9	25·449	59·123	37·4	19·086	44·342	24·9	12·724	29·561
52	51·0	26·520	61·611	38·2	19·890	46·208	25·5	13·260	30·805
53	52·1	27·613	64·151	39·0	20·709	48·113	26·0	13·806	32·075
54	53·3	28·782	66·866	39·9	21·586	50·149	26·6	14·391	33·433
55	54·4	29·920	69·510	40·8	22·440	52·132	27·2	14·960	34·755
56	55·5	31·080	72·205	41·6	23·310	54·153	27·7	15·540	36·102
57	56·6	32·262	74·951	42·4	24·196	56·213	28·3	16·131	37·475
58	57·8	33·524	77·883	43·3	25·143	58·412	28·9	16·702	38·941
59	58·9	34·751	80·734	44·1	26·063	60·550	29·4	17·375	40·367
60	60·0	36·300	83·635	45·0	27·000	62·726	30·0	18·000	41·817

EVAPORATION.

Evaporation on flat country is about 50% less than that on an undulating rocky one.

Mean daily evaporation in India ·20 inches.

Greatest evaporation in 24 hours ·56 inches.

Surface evaporation of water (pole).

If T = Temperature of atmosphere in Degrees F.

t = Dew point.

v = Velocity of wind in miles per hour ; and

E = evaporation in inches per day.

Then $E = \dfrac{T^2 - t^2}{k\,(100 - v)}$.

Where k = 80 for summer and 100 for winter temperature.

Loss of water by Evaporation in feet.

	October.	November.	December.	January.	February.	March.	April.	May.	Total of eight months.
Rajputana ..	·49	·35	·29	·29	·35	·55	·73	·81	3·86
Bombay ..	·65	·49	·37	·44	·34	·44	·69	·99	4·41
Nagpur ..	·50	·42	·37	·33	·32	·48	·76	·59	3·77

ABSORPTION.

According to Mr. Beresford :—

(*i*) The loss of water by absorption is greater when a canal is in cutting than when it is in embankment.

(*ii*) When the other conditions are constant the loss by absorption varies directly as the wetted perimeter of the channel.

(*iii*) Under ordinary conditions the loss by absorption between head of a distributary and any point L miles from the head can be expressed :—Loss $= AL^x$

Where A = the loss actually ascertained by experiment in the first mile.

x = the power to which L is raised, it varies from $\frac{4}{8}$ to $\frac{6}{7}$.

(*iv*) There is more waste by absorption in village channels than in all other parts of irrigation system.

(*v*) The loss by absorption is much greater in new canals than in old ones.

The following Table shows loss of canal water at different stages.

Authority.	In Main Caal.	In Distributary.	In Water Course.	In Cultivation.	Total.
Mr. Ives. ..	15%	7%	22%	27%	71%
Mr. Kennedy ..	20%	6%	21%	25%	72%
Mr. Varma (more recent).	15%	7%	17·5%	8·5%	48%

The most approved formula for loss by absorption on the Punjab canal is $P = c\sqrt{d}\frac{wL}{1000000}$

Where P = loss by absorption in any reach per second in c. ft.
c = a constant usually taken as 3·5.
d = depth of supply in feet.
w = width of water surface in feet.
L = length of reach in feet.

DUTY OF WATER.

The duty of a canal is expressed by the number of acres brought to maturity by each cause of average discharge during the currency of the crop.

The full supply factor of any canal or water channel is the number of acres brought to maturity by each cusec of full supply.

Duty formulæ :—

(*i*) If D = duty of water, and

B = Base of duty, *i.e.*, the number of days during which the supply of one cusec runs in order to mature the crop defined by the duty.

Then $V = \frac{B}{D} \times 86,400$

V = the volume of water in c. ft. used in maturing 1 acre of crop.

(*ii*) $\Delta = \frac{B}{D} \times 1{\cdot}983 = 2\left(\frac{B}{D}\right)$ nearly = total aggregate depth in feet, over an area of ' acre.

(*iii*) If x = the discharge in cusecs necessary to irrigate a given number of acres of crops (A) with a given duty (D) and base (B), then:—

$$x = \frac{A}{D} = \frac{A \times \Delta}{1 \cdot 983B} = \frac{1}{2}\left(\frac{A \times \Delta}{B}\right) \text{ nearly.}$$ (*Buckley's Irrigation Pocket Book.*)

The following table gives the actual duty of water on the following Punjab Canals for years 1920-21 to 1924-25:—

Canal.	Crop.	1920-21.	1921-22.	1922-23.	1923-24.	1924-25
Western Jumna ..	Kharif	110	130	110	120	120
	Rabi	190	170	145	150	170
Upper Bari Doab ..	Kharif	110	120	120	110	120
	Rabi	260	240	230	260	200
Lower Bari Doab ..	Kharif	80	100	70	90	90
	Rabi	120	160	140	130	140
Sirhind Canal ..	Kharif	110	110	140	130	110
	Rabi	210	200	190	210	180
Upper Chenab ..	Kharif	80	90	90	80	70
	Rabi	150	150	210	220	200
Lower Chenab ..	Kharif	90	90	90	120	110
	Rabi	200	210	230	240	225
Upper Jhelum ..	Kharif	90	80	70	80	80
	Rabi	180	200	250	220	170
Lower Jhelum ..	Kharif	80	100	80	110	80
	Rabi	170	200	240	210	180

As a rough average it may be reckoned that one cubic foot a second will irrigate from 140 to 160 acres of Rabi crops and 70 to 80 acres of Kharif.

One cusec running for 100 days will irrigate about 118·7 acres to a depth of 20 inches.

An acre foot lifted one foot per day corresponds to ·568 H. P.

Discharge Tables (in cubic feet per second) for Rajbahas and minors, when Side slope is ½ to 1.

SLOPES.

Depth of water in feet.	in 10,(0·1 per	1 in 0·125	6, per	,714 o er 100		in 4,444 25 per 10	1 in 4,(·25 per	1 in , 275 per	per	1 in 3,0 0·325 per	1 in 2·85 0·35 per 10	in z,(75 per	1 ·4 per
Bed width, 2 feet.													
			·3			·3	·3	·3	·4	·4		·4	·4
·6			·4			·4	·5	·5	·6	·6		·6	6
·7			·5			·5	·6	·6	·7	·7		·8	·8
·8			·6			·7	·8	·8	·9	·9		1	1
·9	·6	·7	·7			·9	1	1	1	1		1	1
1·0	·8	·9	·9			1	1	1	1	1		1	1
1·2	1	1	1			2	2	2	2	2		2	2
1·4	2	2	2			2	2	2	2	2		3	3
1·6	2	2	2			3	3	3	3	3		3	3
1·8	2	2	3			3	3	4	4	4		4	4
2·0	3	3	4			4	4	4	5	5		5	5
Bed width, 3 feet.													
·5	·3	·4	·4	·5	·5	·5	·5	·6	·6	·6	·6	·7	·7
·6	·5	·6	·6	·7	·7	·7	·7	·8	·8	·8	·9	·9	1
·7	·6	·7	·7	·8	·9	·9	1	1	1	1	1	1	1
·8	·8	·9	·9	1	1	1	1	1	1	1	1	1	2
·9	1	1	1	1	1	1	1	2	2	2	2	2	2
1·0	1	1	1	1	2	2	2	2	2	2	2	2	2
1·2	2	2	2	2	2	2	2	3	3	3	3	3	3
1·4	2	2	3	3	3	3	3	4	4	4	4	4	4
1·6	3	3	3	4	4	4	4	5	5	5	5	5	5
1·8	3	4	4	4	5	5	5	6	6	6	6	6	7
2·0	4	5	5	5	6	6	6	7	7	7	8	8	8
Bed width, 4 feet.													
·5	·4	·4	·5	·5	·6	·6	·7	·7	·8	·8	·8	·9	·9
1·0	2	2	2	2	2	2	2	3	3	3	3	3	3
1·5	3	3	4	4	5	5	5	5	6	6	6	6	7
2·0	6	6	7	7	8	8	9	9	10	10	10	11	11
2·5	8	9	10	11	12	13	13	14	14	15	15	16	17

Discharge Tables (in cubic feet per second) for Rajbahas and minors, when Side slope is ½ to 1.—contd.

Depth of water in feet.	Slopes.												
	1 in 10,000 or 0·1 per 1000.	1 in 8,000 or 0·125 per 1000.	1 in 6,666 or 0·15 per 1000.	1 in 5,714 or 0·175 per 1000.	1 in 5,000 or 0·2 per 1000.	1 in 4,444 or 0·225 per 1000.	1 in 4,000 or 0·25 per 1000.	1 in 3,636 or 0·275 per 1000.	1 in 3,333 or 0·3 per 1000.	1 in 3,077 or 0·325 per 1000.	1 in 2,857 or 0·35 per 1000.	1 in 2,666 or 0·375 per 1000.	1 in 2,500 or 0·4 per 1000.
	Bed width, 5 feet.												
·5	·6	·6	·7	·7	·8	·8	·9	·9	1	1	1	1	1
1·0	2	2	2	3	3	3	3	3	3	4	4	4	4
1·5	4	5	5	6	6	6	7	7	7	8	8	8	8
2·0	7	8	9	9	10	11	11	12	12	13	13	14	14
2·5	11	12	13	14	15	16	17	18	18	19	20	20	21
3·0	15	16	18	19	21	22	23	24	25	27	27	28	29
	Bed width, 6 feet.												
·5	·7	·8	·9	·9	1	1	1	1	1	1	1	1	1
1·0	2	3	3	3	4	4	4	4	4	5	5	5	5
1·5	5	6	6	7	7	8	8	9	9	9	10	10	10
2·0	9	10	11	12	12	13	14	14	15	16	16	17	17
2·5	12	14	15	17	18	19	20	21	22	23	24	25	26
3·0	18	20	22	24	25	27	28	30	31	32	33	34	36
	Bed width, 7 feet.												
·5	.8	.9	1	1	1	1	1	1	1	1	1	2	2
1·0	3	3	4	4	4	4	5	5	5	5	6	6	6
1·5	6	7	7	8	9	9	10	10	11	11	11	12	12
2·0	16	11	13	14	15	15	16	17	18	19	19	20	21
2·5	15	17	19	20	22	23	24	25	26	27	28	29	30
3·0	21	23	26	27	30	32	33	35	36	38	39	41	42
	Bed width, 8 feet.												
·5	1	1	1	1	1	1	1	1	1	2	2	2	2
1·0	3	4	4	5	5	5	5	6	6	6	6	7	7
1·5	7	8	9	9	10	11	11	12	12	13	13	14	14
2·0	12	13	15	16	17	18	19	20	21	21	22	23	24
2·5	18	20	22	23	25	26	28	29	31	32	33	34	35
3·0	24	27	30	32	34	36	38	40	42	44	46	47	49

Discharge Tables (in cubic feet per second) for Rajbahas and minors, when Side slope is ½ to 1—**contd.**

SLOPES.

Bed width, 9 feet.

Depth of water in feet.	in 10 pe	1 in 8000 or 0·125 per 1000	,666 or ·1000.	in 5,714 or 5 per 1000	1 in 5, 0·2 per	44 pe 100	in 4,… 0·25 per 1…	1 in 3,636 or 0·275 per 1000.	1 in 3,3 0·3 per 1	in 3,077 or ·325 per 1000	1 in 2, ·35 per	1 in 2,66 ·375 per
·5	1	1	1	1	1	2	2	2	2	2	2	2
1·0	4	4	5	5	5	6	6	6	7	7	7	8
1·5	8	9	10	11	11	12	13	13	14	15	15	16
2·0	14	15	17	18	19	20	21	23	24	24	25	26
2·5	20	22	25	27	28	30	32	33	35	36	37	39
3·0	28	31	34	37	39	42	44	46	48	50	52	54
3·5	36	40	44	48	51	54	57	60	63	65	68	70

Bed width, 10 feet.

Depth of water in feet.	in 10 pe	1 in 8000 or 0·125 per 1000	,666 or ·1000.	in 5,714 or 5 per 1000	1 in 5, 0·2 per	44 pe 100	in 4,… 0·25 per 1…	1 in 3,636 or 0·275 per 1000.	1 in 3,3 0·3 per 1	in 3,077 or ·325 per 1000	1 in 2, ·35 per	1 in 2,66 ·375 per
·5	1	1	1	2	2	2	2	2	2	2	2	2
1·0	4	5	5	6	6	7	7	7	8	8	8	8
1·5	9	10	11	12	13	14	14	15	16	16	17	18
2·0	15	17	19	20	22	23	24	25	26	28	29	30
2·5	23	25	28	30	32	34	36	37	39	41	42	44
3·0	31	35	38	41	44	47	49	52	54	56	58	60
3·5	41	45	50	54	57	61	64	67	70	73	76	79

Bed width, 12 feet.

Depth of water in feet.	in 10 pe	1 in 8000 or 0·125 per 1000	,666 or ·1000.	in 5,714 or 5 per 1000	1 in 5, 0·2 per	44 pe 100	in 4,… 0·25 per 1…	1 in 3,636 or 0·275 per 1000.	1 in 3,3 0·3 per 1	in 3,077 or ·325 per 1000	1 in 2, ·35 per	1 in 2,66 ·375 per	
·5	1	2	2	2	2	2	2	2	2	3	3	3	3
1·0	5	6	6	7	8	8	8	9	9	10	10	10	11
1·5	11	12	14	15	16	17	18	18	19	20	21	22	22
2·0	19	21	23	25	26	28	30	31	32	34	35	36	37
2·5	27	31	34	36	39	41	44	46	48	50	51	53	55
3·0	38	42	46	50	54	57	60	63	66	68	71	73	76
3·5	50	55	61	65	70	74	78	82	86	89	92	96	99
4·0	62	69	77	83	88	94	99	104	108	112	116	121	125
4·5	76	85	93	100	108	114	120	126	132	137	142	147	152
5·0	91	102	112	121	129	137	144	151	158	165	171	177	183

Discharge Tables (in cubic feet per second) for Rajbahas and minors, when Side slope is ½ to 1.—contd.

Depth of water in feet.	1 in 10,000 or 0·1 per 1000.	1 in 8,000 or 0·125 per 1000	1 in 6,666 or 0·15 per 1000.	1 in 5,714 or 0·175 per 1000.	1 in 5,000 or 0·2 per 1000.	1 in 4,444 or 0·225 per 1000.	1 in 4,000 or 0·25 per 1000.	1 in 3,636 or 0·275 per 1000.	1 in 3,333 or 0·3 per 1000.	1 in 3,077 or 0·325 per 1000.	1 in 2,857 or 0·35 per 1000.	1 in 2,666 or 0·375 per 1000.	1 in 2,500 or 0·4 per 1000.
	SLOPES.												
	Bed width, 14 feet.												
·5	2	2	2	2	2	3	3	3	3	3	3	3	3
1·0	6	7	7	8	9	9	10	10	11	11	12	12	12
1·5	13	15	16	17	19	20	21	22	23	24	25	25	26
2·0	22	24	27	29	31	33	35	36	38	40	41	43	44
2·5	33	36	40	43	46	49	51	54	56	59	61	63	65
3·0	45	50	55	59	63	67	71	74	78	81	84	87	90
3·5	59	65	72	77	83	92	93	97	101	105	110	113	117
4·0	74	82	90	97	104	110	116	122	128	133	138	143	147
4·5	90	100	110	119	127	135	142	149	156	162	168	174	180
5·0	108	120	132	142	152	161	170	178	186	192	202	209	215
	Bed width, 16 feet.												
·5	2	2	2	3	3	3	3	3	3	3	4	4	4
1·0	7	8	9	9	10	11	11	12	12	13	13	14	14
1·5	15	17	19	20	22	23	24	25	26	27	28	29	30
2·0	25	28	31	34	36	38	40	42	44	46	48	49	51
2·5	38	42	46	50	53	56	60	62	65	68	71	73	75
3·0	52	58	63	68	73	77	81	85	90	93	97	100	104
3·5	68	75	83	89	96	101	107	112	117	122	127	131	135
4·0	85	95	104	112	121	128	134	141	147	153	159	165	170
4·5	104	116	128	138	147	156	165	173	181	188	195	202	208
5·0	124	138	152	164	175	186	196	206	215	224	233	240	248
	Bed width, 18 feet.												
·5	2	2	3	3	3	3	3	4	4	4	4	4	4
1·0	8	9	10	11	11	12	13	14	14	15	15	16	16
1·5	17	19	21	22	24	26	27	29	30	31	32	33	34
2·0	29	32	35	38	41	43	46	48	50	52	54	56	58
2·5	43	48	52	57	61	64	68	71	74	77	80	83	86
3·0	59	66	72	78	83	88	93	98	102	106	110	114	118
3·5	77	86	94	102	109	115	122	128	133	139	144	149	154
4·0	97	108	118	128	137	145	153	160	167	174	181	187	194
4·5	118	131	145	156	167	177	187	196	205	213	221	229	236
5·0	141	157	173	186	200	211	223	234	244	254	264	273	282

Discharge Tables (in cubic feet per second) for Rajbahas and minors, when Side slope is ½ to 1—contd.

SLOPES.

Depth of water in feet.	1 in 10,[…] 0·1 per […]	[…] 8,[…] pe[…]	[…] in […] pe[…]	[…] in […]4 or 75 […] 1000	1 in 5,[…] ·2 per […]	1 in […]44 0·225 […]10	1 in 4,[…] 0·25 pe[…]00[…]		1[…],33[…] or ·3 per […]	1 in 3,[…] ·325 pe[…]	1 […]2,[…] or ·3[…] per 1[…]0	1 in 2,6[…] or ·375 per […]	1 in 2[…] 0·4 per […]
					Bed width, 20 feet.								
·5	2	3	3	3	3	4	4	4	4	4	5	5	5
1·0	9	10	11	12	13	14	15	15	16	17	17	18	18
1·5	19	21	24	26	27	29	31	32	33	35	36	37	39
2·0	32	36	40	43	46	48	51	54	56	58	61	63	65
2·5	48	54	59	64	68	72	76	80	84	87	90	93	97
3·0	66	73	81	87	93	99	104	109	114	119	123	128	132
3·5	86	96	106	114	122	129	136	143	150	156	161	167	173
4·0	108	120	132	142	153	162	171	179	187	195	203	209	216
4·5	133	148	162	175	188	199	210	220	230	239	248	256	265
5·0	159	176	194	209	224	238	251	263	275	285	294	307	357
					Bed width, 22 feet.								
·5	3	3	3	4	4	4	4	4	5	5	5	5	5
1·0	10	11	12	13	14	14	15	16	17	18	18	19	19
1·5	21	24	26	28	30	32	34	35	36	38	40	41	43
2·0	36	40	44	47	51	54	57	59	62	65	67	69	72
2·5	53	60	65	70	75	80	84	88	92	96	100	103	106
3·0	73	82	90	97	104	110	116	121	127	132	137	142	146
3·5	95	106	117	126	135	143	151	158	165	172	179	185	191
4·0	120	134	140	159	170	180	190	198	208	217	225	233	240
4·5	146	164	180	194	207	220	232	243	254	265	274	284	294
5·0	175	196	215	232	218	263	277	291	301	316	328	340	351
5·5	205	230	252	272	91	308	326	391	357	371	385	399	411
6·0	238	266	292	315	337	357	377	395	413	420	446	460	476
					Bed width, 24 feet.								
·5	3	3	4	4	4	4	5	5	5	5	5	6	6
1·0	11	12	13	15	16	16	17	18	19	20	21	21	22
1·5	23	26	28	31	33	35	37	38	40	42	44	45	46
2·0	39	44	48	52	56	59	62	65	68	71	73	76	79
2·5	58	65	72	77	82	88	92	97	101	105	109	163	115
3·0	80	90	98	106	114	121	127	133	139	145	150	156	161
3·5	105	118	128	139	148	157	166	174	183	189	197	203	210
4·0	132	147	166	174	187	198	209	219	229	238	247	255	264
4·5	161	180	198	212	228	242	255	267	279	291	302	313	322
5·0	193	215	236	255	272	289	305	319	334	347	360	373	385
5·5	226	253	279	300	320	340	358	376	392	409	424	439	453
6·0	261	292	320	346	370	392	413	433	453	471	489	506	523

NOTCHES.

Gauging small quantites of Water through a Triangle notch.

The notch must be a right angled notch with thin edges.

H = height above bottom of notch in inches.

Table of Discharge, Gallons per Minute.

H	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	2·01	2·51	3·12	3·81	4·59	5·45	6·45	7·45	8·59	9·84
2	11·19	12·64	14·20	15·86	17·65	19·55	21·56	23·42	25·95	28·32
3	30·84	33·46	36·23	39·12	42·15	45·33	48·64	52·09	55·67	59·41
4	63·30	65·79	71·50	75·83	80·32	83·74	89·89	94·72	99·85	105·12

5 inches = 110 57.

Water dammed,—not in motion.

Discharge in gallons = $1·978\ H^2 \sqrt{H}$, or (Thomson's formula) · $1·91\ H^{2\ 5}$

Useful Data in pipe Calculations.

Diameter.		Perimeter.	Area.	Area. / Perim.	Diameter.		Perimeter.	Area.	Area. / Perim.
ins.	feet.		feet.		ins.	feet.		feet.	
½	·04167	·1309	·00136	·0104	14	1·1667	3·6651	1·0690	·2917
¾	·0625	·1964	·00307	·0156	16	1·3333	4·1887	1·3962	·3333
1	·0833	·2618	·00545	·0208	18	1·5	4·7123	1·7672	·3750
1½	·1250	·3927	·01227	·0313	20	1·6667	5·2360	2·1810	·4167
1¾	·1458	·4582	·01670	·0365	24	2·	6·2832	3·1416	·5
2	·1667	·5236	·02182	·0417	27	2·25	7·0686	3·9761	·5625
3	·25	·7854	·04009	·0625	30	2·5	7·8540	4·9087	·625
4	·3333	1·0472	·08727	·0833	33	2·75	8·6343	5·9396	·6875
6	·5	1·5717	·19636	·1257	36	3·	9·4247	7·0686	·75
8	·6667	2·0943	·34906	·1667	30	3·333	10·472	8·7265	·8333
10	·8333	2·6180	·54542	·2083	44	3·667	11·420	10·560	·9167
12	1·0	3·1416	·78540	·25	48	4·	12·566	12·566	1·0

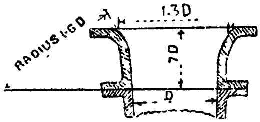
The Mean Hydraulic Radius = Area ÷ Perimeter = ·25 diameter in feet.

The Area in Feet = The number of Cubic Feet contained in 1 lineal foot of the pipe. The Area × 62·4 = pounds contained in 1 lineal foot or gallons in every 10 lineal feet of the pipe.

Fire Jets from Smooth Nozzles. (*Freeman.*)
P = Pressure of water, lbs. per square inch, at entrance of nozzle.
H = Maximum height of an effective fire-stream in feet.
D = Maximum horizontal distance of ,, ,,
Q = Discharge per minute in gallons.

P. lbs. per sq. in.	¾ in. nozzle.			1 in. nozzle.			1¼ in. nozzle.		
	H	D	Q	H	D	Q	H	D	Q
10	17	..	43	18	..	77	19	..	123
20	33	72	63	35	77	110	37	83	174
30	48	..	75	51	..	140	53	..	213
40	60	112	87	64	133	155	67	148	246
50	67	..	97	73	..	173	77	..	275
60	72	136	107	79	167	189	85	186	311
70	76	..	114	85	..	205	91	..	326
80	79	153	122	89	189	219	95	213	348
90	81	..	130	92	..	232	99	..	369
100	83	167	136	96	205	245	101	236	389

Bell-mouth Entrance to Pipes.
K = Coefficient of influx.
H = Head of water above bell-mouth in feet.



If H =	5	10	15	20	25	30	35	40	45	50
K =	·968	·975	·978	·982	·986	·988	·990	·991	·993	·994

Coefficients of Efflux for Short Pipes.

Length÷diameter	1	5	10	25	50	75	100	125
Coefficient. . . .	·62	·792	·770	·714	·643	·588	·548	·512

Length÷diameter	150	175	200	225	250	275	300
Coefficient. . .	·485	·462	·440	·420	·405	·386	·378

NOTCHED FALLS ON DISTRIBUTARIES.

Canal notches with complete fall.

$$D = \tfrac{2}{3} C\sqrt{2g}\,\left(l\,d^{\frac{3}{2}} + \tfrac{2}{5} n\,d^{\frac{5}{2}}\right).$$

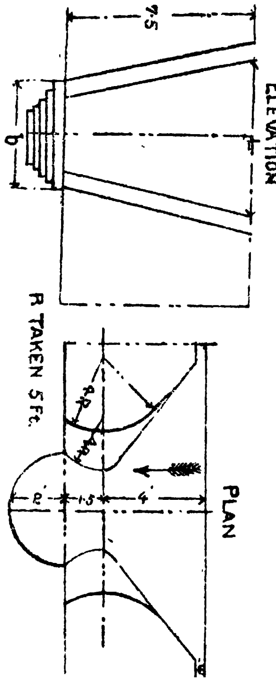
Where l length of the cill of notch in feet.
n 2 tan α where α is the angle made by the sides of the notch with the vertical.
c = coefficient of discharge which is ·85 for canal notches and ·80 for Distributary notches. (Kennedy).

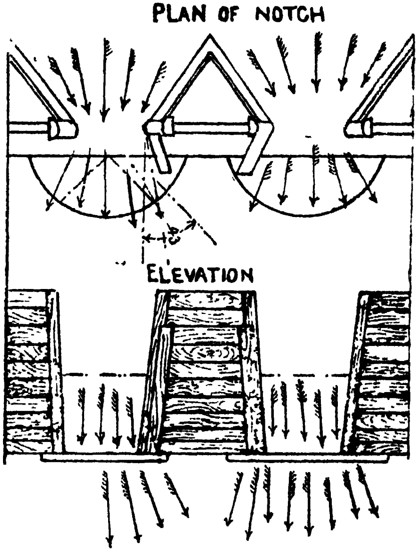
D = discharge in cubic feet per second.
d = depth of water in feet above cill of notch and measured to the normal surface a few feet upstream of the notch.

$$\left.\begin{array}{l}\text{Tan } \alpha = m_1 D d \\ l = m_2 D d^{-\frac{3}{2}}\end{array}\right\} \ldots\ldots \text{Garret.}$$

Where m_1 and m_2 are coefficients of which the value depends on the ratio $\frac{E}{d}$, E being the submersion in feet.

(*Notches used on Distributaries*).





The above forms of notches have been found best in the light of experiments made on the Punjab Canals.

At the foot of each of the above notches there is a lip plate projecting beyond the outer edge of the breast wall which has a great influence in spreading the stream and determining the form of falling water.

Table of $d^{-\frac{3}{2}}$ *when* $d = 1$ *to* 15

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	·10	·867	·760	·674	·603	·544	·494	·451	·414	·382
2	·354	·328	·306	·286	·268	·253	·238	·225	·213	·202
3	·192	·183	·175	167	·159	·153	·146	·140	·138	·130
4	·125	·120	·116	·112	·108	·105	·1051	·0981	·095	·0921
5	·0874	·0868	·0844	·082	·0797	·0775	·0754	·0734	·0715	·0697
6	·068	·0663	·0647	·0632	·0618	·0604	·059	·0577	·0564	·0552
7	·0540	·0529	·0518	·0537	·0497	·0487	·0477	·0468	·0459	·045
8	·0442	·0404	·0426	·0418	·041	·0403	·0396	·0389	·0384	·0376
9	·037	·0361	·0358	·0352	·0346	·0341	·0336	·3311	·0326	·034
10	·0316	·0310	·0307	·0302	·0298	·0293	·0289	·0285	·0281	·0277
11	·0274	·0270	·0266	·0263	·0259	·0256	·0253	·0249	·0246	·0343
12	·024	·0230	·0234	·0231	·0229	·0226	·0223	·0221	·0218	·0215
13	·0213	·210	·0208	·0206	·0203	·0201	·0199	·0197	·0195	·0193
14	·019	·0188	·0186	·0184	·0183	·0181	·0179	·0177	·0175	·0173
15	·0172	..	..	..	..	..	..	..	..	..

Table of $d^{-\frac{5}{2}}$ *when* $d = 1$ *to* 15.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	1	·787	·632	·513	·431	·362	·308	·265	·230	·200
2	177	·156	·139	·124	·112	·101	·0917	·0845	·0762	·0699
3	·064	·059	·0546	·0506	·0469	·0436	·0407	·0379	·0355	·0334
4	·0313	·0294	·0277	·0261	·0246	·0233	·0220	·0209	·0198	·0188
5	·0179	·0170	·0162	·0155	·0148	·0141	·0135	·0129	·0123	·0118
6	·0113	·0109	·0104	·0100	·00965	·00928	·00894	·00861	·00829	·0080
7	·00771	·00744	·00719	·00694	·00671	·00649	·00628	·00608	·00588	·0057
8	·00552	·00565	·00519	·00504	·00489	·00475	·00461	·00448	·00435	·00423
9	·00411	·0040	·00389	·00379	·00369	·00359	·0035	·00341	·00330	·00324
10	·00316	·00308	·00301	·00294	·00286	·00279	·00273	·00267	·00260	·00255
11	·00249	·00243	·00238	·00233	·00227	·00223	·00218	·00213	·00201	·00204
12	·00200	·00196	·00192	·00158	·00184	·00181	·00177	·00174	·00170	·00167
13	·00168	·00161	·00158	·00155	·00152	·00149	·001466	·00144	·00141	·00138
14	·00136	·00133	·00131	·00129	·00127	·00124	·00122	·00120	·00118	·00116
15	·001148	..	..	.	..	..	..	..	..	..

Table showing $\frac{5}{2}$ Powers of N, i.e. $\sqrt{N^5}$ when $N = 1$ to 10.

N.	·0	·1	.2	·3	·4	·	·6	·7	·8	·9
	Decimals in N.									
0	0·00	·003	·017	·049	·101	0·177	·278	·409	·572	·767
1	1·000	1·270	1·578	1·926	2·318	2·756	3·238	3·767	4·347	4·977
2	5·657	6·390	7·178	8·021	8·924	9·852	10·90	71·98	13·12	14·29
3	15·59	16·92	18·31	19·78	21·29	22·92	24·59	26·33	28·15	29·87
4	32·00	34·04	36·15	38·34	40·61	42·96	45·39	47·88	50·48	53·15
5	55·90	58·75	61·66	64·57	67·76	70·96	74·21	77·57	80·91	84·53
6	88·18	91·90	95·72	99·62	103·62	107·70	111·9	116·2	120·5	125·0
7	129·6	134·3	139·1	143·9	148·9	154·0	159·2	164·5	169·9	175·4
8	181·0	186·7	191·4	198·4	204·5	210·6	216·8	223·2	229·6	236·3
9	243·0	249·8	256·9	263·6	270·9	278·1	285·5	293·1	300·6	308·3
10	316·2	..	..	..	..	..	..	..	..	..

Table showing $\frac{3}{2}$ Powers of N i.e. $\sqrt{N^3}$ when $N = 1$ to 10.

N.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	1·0	1·153	1·313	1·482	1·656	1·837	2·024	2·217	2·414	2·619
2	2·828	3·043	3·263	3·488	3·718	3·953	4·192	4·436	4·685	4·839
3	5·196	5·458	5·725	5·994	6·269	6·548	6·831	7·117	7·407	7·702
4	8·00	8·301	8·607	8·916	9·229	9·546	9·867	10·19	10·51	10·84
5	11·18	11·501	11·85	12·22	12·54	12·89	13·24	13·6	13·96	14·32
6	14·7	15·06	15·43	15·81	16·19	16·57	16·95	17·34	17·72	18 12
7	18·52	18·9	19·31	19·72	20·12	20·54	20·95	21·37	21·79	22·21
8	22·63	23·05	23·47	23·91	24·34	24·78	25·21	25·66	26·11	26·56
9	27·6	27·45	27·9	28·36	28·82	29·28	29·75	30·22	30·68	31·15
10	31·62	32·09	32·57	33·05	33·53	34·02	34·51	35·0	35·49	35·98

Table showing values of m_1 and m_2 for coefficient of Discharge.
$C = 0{\cdot}70$ *for channels carrying up to* 300 *cusecs.*

$\frac{E}{d}$	m_1	m_2	$\frac{E}{d}$	m_1	m_2	$\frac{E}{d}$	m_1	m_2
0	·0550	·224	·30	·0858	·208	·60	·1650	·180
·01	·0551	·224	·31	·0880	·207	·61	·1683	·180
·02	·0553	·224	·32	·0903	·206	·62	·1716	·180
·03	·0555	·224	·33	·0927	·204	·63	·1750	·179
·04	·0557	·224	·34	·0951	·203	·64	·1784	·179
·05	·0560	·224	·35	·0976	·202	·65	·1819	·179
·06	·0563	·223	·36	·1000	·201	·66	·1855	·179
.07	·0567	·223	·37	·1025	·199	·67	·1893	·179
·08	·0571	·223	·38	·1050	·198	·68	·1932	·179
·09	·0576	·223	·39	·1075	·197	·69	·1972	·179
·10	·0582	·222	·40	·1100	·196	·70	·2014	·179
·11	·0588	·222	·41	·1125	·195	·71	·2058	·179
·12	·0595	·222	·42	·1150	·194	·72	·2104	·179
·13	·0603	·221	·43	·1175	·192	·73	·2152	·180
·14	·0612	·221	·44	·1201	·191	·74	·2202	·180
·15	·0621	·220	·45	·1227	·190	·75	·2254	·181
·16	·0631	·220	·46	·1253	·189	·76	·2309	·182
·17	·0642	·219	·47	·1279	·188	·77	·2368	·183
·18	·0654	·219	·48	·1305	·188	·78	·2431	·184
·19	·0667	·218	·49	·1331	·187	·79	·2499	·185
·20	·0681	·217	·50	·1358	·186	·80	·2572	·186
·21	·0696	.217	·51	·1385	·185	·81	·2649	·188
·22	·0711	.216	·52	·1412	·184	·82	·2731	·190
·23	·0727	·215	·53	·1440	·184	·83	·2818	·193
·24	·0744	·214	·54	·1468	·183	·84	·2911	·196
·25	·0761	·213	·55	·1497	·183	·85	·3010	·199
·26	·0779	·212	·56	·1526	·182	·86	·3117	·202
·27	·0798	·211	·57	·1556	·182	·87	·3238	·206
·28	·0817	·210	·58	·1587	·181	·88	·3376	·210
·29	·0837	·209	·59	·1618	·181	·89	·3546	·214

(Buckley's Irrigation Pocket Book.)

Table showing values of m_1 and m_2 for Coefficient of Discharge.
C = 0·75 *for channels carrying over* 300 *cusecs.*

$\frac{E}{d}$	m_1	m_2	$\frac{E}{d}$	m_1	m_2	$\frac{E}{d}$	m_1	m_2
0	·0513	·209	·30	·0801	·194	·60	·1540	·168
·01	·0514	·209	·31	·0821	·193	·61	·1571	·168
·02	·0516	·209	·32	·0842	·192	·62	·1602	·168
·03	·0518	·209	·33	·0864	·191	·63	·1634	·167
·04	·0520	·209	·34	·0887	·190	·64	·1666	·167
·05	·0523	·209	·35	·0911	·188	·65	·1698	·167
·06	·0526	·209	·36	·0934	·187	·66	·1731	·167
·07	·0530	·208	·37	·0957	·186	·67	·1766	·167
·08	·0534	·208	·38	·0980	·185	·68	·1802	·167
·09	·0538	·208	·39	·1004	·184	·69	·1840	·167
·10	·0543	·208	·40	·1027	·183	·70	·1880	·167
·11	·0549	·207	·41	·1051	·182	·71	·1922	·167
·12	·0556	·207	·42	·1074	·181	·72	·1965	·167
·13	·0563	·207	·43	·1098	·180	·73	·2010	·168
·14	·0571	·206	·44	·1121	·179	·74	·2056	·168
·15	·0580	·206	·45	·1145	·178	·75	·2104	·169
·16	·0590	·205	·46	·1169	·177	·76	·2155	·170
·17	·0600	·205	·47	·1193	·176	·77	·2210	·170
·18	·0611	·204	·48	·1217	·175	·78	·2269	·171
·19	·0623	·203	·49	·1240	·174	·79	·2332	·172
·20	·0636	·203	·50	·1267	·174	·80	·2400	·174
·21	·0649	·202	·51	·1293	·173	·81	·2472	·176
·22	·0663	·201	·52	·1319	·172	·82	·2548	·178
·23	·0678	·201	·53	·1345	·172	·83	·2629	·180
·24	·0694	·200	·54	·1371	·171	·84	·2716	·183
·25	·0710	·199	·55	·1397	·170	·85	·2809	·186
·26	·0727	·198	·56	·1424	·170	·86	·2909	·189
·27	·0745	·197	·57	·1452	·169	·87	·3022	·192
·28	·0763	·196	·58	·1480	·169	·88	·3150	·196
·29	·0782	·195	·59	·1509	·169	·89	·3309	·200

(*Buckley's Irrigation Pocket Book.*)

Dimensions of notches.—The readers of this book are not supposed to ever get a chance of working out the dimensions of notches themselves; and the methods used to find out dimensions are too difficult to be easily understood unless one is quite competent in higher theories of mathematics. We, therefore, give here a few tables of already calculated dimensions which can be usefully used for small distributary notches.

Table of Notch dimensions for certain particular cases.

INCOMPLETE FALLS. KUTTER'S N=0·025

Height of fall.	Discharge.	DATA.			RESULTS.		REMARKS.
		Bed.	F. S. Depth.	Bed Slope.	b	s	
1·0	10	6	1·6	1 in 3636	1·0	0·5	
1·0	20	6·5	2·2	,,	1·1	0·55	
1·0	50	10·5	2·9	1 in 4000	1·87	0·85	b=Bottom width of
1·0	100	12·5	3·85	,,	2·3	1·05	Notch.
1·5	10	6	1·6	1 in 3636	1·25	0·35	s=Side slope ratio.
1·5	25	9	2·15	1 in 4000	1·65	0·525	d=depth of water.
1·5	50	10·5	2·9	,,	2·1	0·59	T=Top width of
1·5	100	12·5	3·85	,,	2·3	0·735	Notch. T=b+2sd.
2·0	30	9 5	2·35	,,	1·60	0·48	
2·0	40	10	2·6	,,	1·89	0·49	
2·0	50	10·5	2·9	,,	2·3	0·425	
2·0	100	12·5	3·85	,,	2·41	0·63	
2·5	60	11·0	3·10	,,	2·16	0·45	
2·5	80	12·0	3·5	,,	2·5	0·40	
2·5	120	16·0	3·85	1 in 4444	3·25	0·52	
2·5	150	17	4·2	,,	3·72	0·41	
3·0	70	11·5	3·30	1 in 4000	2·56	0 19	
3·0	90	12·5	3·7	,,	3·04	0·105	
3.0	130	16·5	3·95	1 in 4444	3·82	0.13	
3·0	160	17·5	4·35	,,	3·97	0·14	

Table of Notch dimensions for certain particular cases.—concld.

(Any height) COMPLETE FALLS. (KUTTER'S N=0·025).

Discharge.	Data.			Results.		Remarks.
	Bed.	F. S. Depth.	Bed Slope.	*b*	*s*	
6	4·25	1·4	1 in 3333	0·84	0·175	*b*=Bottom width of Notch.
10	6	1·6	1 in 3636	1·25	0·2	*s*=Side slope ratio.
15	6	1·95	,,	1·25	0·2	*d*=depth of water.
20	6·5	2·2	,,	1·21	0·275	T=Top width of Notch.
25	9	2·15	1 in 4000	1·46	0·438	$T=b+2sd$.
30	9·5	2·35	,,	1·60	0·48	
35	10	2·5	,,	1·58	0·50	
40	10	2·6	,,	1·58	0·50	
45	10	2·8	,,	1·58	0·50	
50	10·5	2·9	,,	1·63	0·516	
60	11	3·1	,,	1·63	0·546	
70	11·5	3·3	,,	1·71	0 57	
80	12	3·5	,,	2·00	0·60	
90	12·5	3·7	,,	2·00	0·63	
100	12·5	3·85	,,	2·00	0·63	
120	16	3·85	1 in 4444	2·34	0·78	
140	17	4·1	,,	2·35	0·96	
160	17	4·35	,,	2·27	0·99	
180	18	4·55	,,	2·33	1·02	
200	18·5	4·65	,,	2·25	1·05	

DISCHARGE OF WATER FROM ORIFICES.

Q = quantity of discharge in c. ft. per second.
A = area of orifice in sq. ft.
V = velocity due to the head of water in ft. per second.
C = constant for different velocities.

$$Q = C. A. V.$$

Values of C for different orifices :—

Sharp edged orifice with converging mouthpiece angle of convergence 13°·21′ .. .. .. C: ·981
Bell-mouth orifice .. .. .. C: ·95 to ·995
Orifice in thin plate .. .. .. C: ·62

For narrow openings whose bottom is on a line with that of reservoir; for abrupt projections and square piers of bridges .. .. .. C = ·86.

For sluices with side walls .. .. .. C = ·62.

Hanbury Brown gives the following as approx values of C for sluices and regulator openings in masonry piers :—

Ordinary lock slucies .. .. .. C = ·62

Small regulator openings with shallow water .. C = ·57

Regulator openings up to 6′ wide with recesses in piers C = ·62

Ditto. between 6 ft. and 13 ft. wide .. .. C = ·72

Ditto. above 13 ft. wide .. .. .. C = ·82

Regulator openings upto 6′ wide with straight and continuous piers. .. .. .. C · ·72

FLOW OF WATER IN CHANNELS.

Kutter's formula for the flow of water in open channels is :—

$V = C\sqrt{RS}$, where the value of cofficient C is:—

$$C = \frac{a + \frac{l}{n} + \frac{m}{S}}{1 + (a + \frac{m}{s})\frac{n}{\sqrt{R}}}$$

With the formula in feet, the constants are:—

a = 41·6604676

l = 1·8113250.

m = 0·0028075.

n = the values generally accepted for n (the coefficient of roughness) are

= 0·009 for well planed timber in perfect order and alignment.

= 0·010 ,, plaster in pure cement and other glazed surfaces.

= 0·011 ,, plaster in sand and cement; iron and other smooth pipes in good order.

= 0·012 ,, unplaned timber.

= 0·013 ,, ashlar and well-laid brick work.

= 0·015 ,, rough brickwork; good stone work in fair order.

= 0·017 ,, brick and stone work in inferior condition.

= 0·020 ,, rubble masonry, coarse brickwork and masonry.

= 0·0225 ,, canals in earth above the average in order and regimen.

= 0·025 ,, canals and rivers in earth in tolerably good order and regimen.

= 0·0275 ,, canals and rivers in earth below the average in order and regimen.

= 0·030 ,, canals and rivers in bad order and regimen.

= 0·035 ,, canals and rivers obstructed by detritus and in bad order and regimen.

= 0·050 ,, torrents encumbered with detritus.

Table showing values of C in the above formula.

R in ft.	S.					
	1 in 1000 or 1 in 1000	·5 in 1000 or 1 in 2000	·3 in 1000 or 1 in 3333	·15 in 1000 or 1 in 6667	·1 in 1000 or 1 in 10000	·05 in 1000 or 1 in 20000
1·0	62·5	61·9	61·2	59·7	58·5	55·7
1·5	68·8	68·4	67·9	66·8	65·9	63·8
2·0	73·2	72·9	72·6	71·9	71·2	69·8
2·5	76·5	76·4	76·2	75·8	75·4	74·6
3·0	79·2	79·2	79·1	79·0	78·8	78·5
4	83·3	83·4	83·6	83·9	84·2	84·9
5·0	86·3	86·0	86·9	87·6	88·3	89·9
6·0	88·7	89·1	89·5	90·6	91·6	93·9
7·0	90·7	91·1	91·7	93·1	94·3	97·3
8·0	92·3	92·8	93·5	95·2	96·6	100·3
9·0	93·7	94·3	95·1	97·0	98·6	102·9
10·0	94·9	95·6	96·5	98·5	100·4	105·1
11·0	96·0	96·7	97·7	99·9	102·0	107·2
12·0	96·0	97·7	98·8	101·2	103·4	109·0

Critical velocity $V_o = \cdot 84 d^{\cdot 64}$.

Table of Kennedy's critical velocities.

d	V_o	*d*	V_o	*d*	V_o	*d*	V_o	*d*	V_o
1·0	·84	3·2	1·77	5·2	2·41	7·2	2·97	9·2	3·48
1·2	·94	3·4	1·84	5·4	2·47	7·4	3·02	9·4	3·52
1·4	1·04	3·6	1·91	5·6	2·53	7·6	3·08	9·6	3·57
1·6	1·13	3·8	1·98	5·8	2·59	7·8	3·13	9·8	3·62
1·8	1·22	4·6	2·04	6·0	2·64	8·0	3·18	10·0	3·69
2·0	1·30	4·2	2·11	6·2	2·70	8·2	3·23	10·5	3·79
2·2	1·39	4·4	2·17	6·4	2·75	8·4	3·28	11·0	3·90
2·4	1·47	4·6	2·23	6·6	2·81	8·6	3·33	11·5	4·01
2·6	1·55	4·8	2·29	6·8	2·87	8·8	3·38	12·0	4·12
2·8	1·63	5·0	2·35	7·0	2·92	9·0	3·43	15·0	4·75
..	..	..	..	..	..	..	..	20·0	5·71

As a guide in grading new channels when the full standard silt proportion is carried, the following table giving approximate the least slope per 1000, which will ensure a mean velocity V_0 and just avoid silting has been compiled from Kennedy's diagrams.

Depth.	DISCHARGE CUSEC.										
	10	25	50	100	200	400	600	1000	2000	4000	6000
2·0	·37	·24	..	..	..	..	..	..	..	..	..
2·5	·55	·30	·22	..	..	..	..	..	..	..	..
3·0	..	·38	·26	·21	..	..	..	..	..	..	..
3·5	..	..	·31	·23	·19	..	..	..	..	..	..
4·0	..	..	·38	·26	·20	·17	..	..	..	..	..
4·5	..	..	..	·29	·22	·18	·16	..	..	..	..
5·0	..	..	..	·33	·24	·19	·17	·15	..	..	..
5·5	..	..	..	..	·26	·20	·18	·16	·15	..	..
6·0	..	..	..	..	·29	·22	·19	·17	·15	·14	..
7·0	..	..	..	..	..	·24	·21	·18	·16	·15	·14
8·0	..	..	..	..	..	..	·23	·20	·17	·16	·15
9·0	..	..	..	..	..	..	..	..	·18	·16	·15
10·0	..	..	..	..	..	..	..	..	..	·17	·16

Table of Kennedy's non-silting V o Channels, N = ·0225.

Slope.	1 in 2000 or ·5 per 1000		1 in 2500 or ·4 per 1000		1 in 2857 or ·35 per 1000		1 in 3333 or ·30 per 1000		1 in 3571 or ·28 per 1000		1 in 3846 or ·26 per 1000		1 in 4166 or ·24 per 1000		1 in 5000 or ·20 per 1000		1 in 5882 or ·17 per 1000	
Discharge.	Bed width.	Depth.	Bed width.	Depth.	Bed width, W.	Depth, d.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.
1	1·4	·9	1·9	·65	2·6	·60	..	..	..	..	..	..	..	..	..	..	..	..
2	1·5	1·25	2·1	·80	2·8	·80	3·8	·65	..	..	..	..	..	..	..	..	..	..
3	1·6	1·3	2·4	1·18	3·0	1·0	4·0	·82	..	..	..	..	..	..	..	..	..	..
4	1·7	1·56	2·5	1·28	3·1	1·2	4·2	1·0	5·1	·9	..	..	..	..	..	..	..	..
6	2	1·8	2·75	1·6	3·4	1·42	4·4	1·22	5·4	1·1	6·5	1·0	9·0	·9	..	..	..	..
8	2	2·1	2·90	1·82	3·5	1·62	4·7	1·42	5·6	1·3	6·8	1·2	9·0	1·0	..	..	..	..
10	2·2	2·2	3·0	2·0	3·7	1·80	5·0	1·60	5·8	1·45	7·0	1·3	9·0	1·1	..	..	..	..
15	2·4	2·62	3·2	2·4	4·0	2·18	5·3	1·90	6·2	1·78	7·2	1·6	9·4	1·42	..	..	..	..
20	2·5	3·0	3·5	2·6	4·2	2·44	5·6	2·2	6·5	2·00	7·8	1·85	9·8	1·64	..	..	..	..
25	..	..	3·7	2·9	4·5	2·70	6·0	2·4	7·0	2·2	8·2	2·1	10·1	1·85	24	1·2	..	..
30	..	..	3·9	3·18	4·8	2·90	6·2	2·6	7·2	2·45	8·4	2·25	10·3	2·0	23	1·35	..	..
35	..	..	4·0	3·42	5·0	3·15	6·5	2·8	7·5	2·60	8·6	2·40	10·6	2·2	2·2	1·4	..	..
40	..	..	4·25	3·6	5·2	3·30	6·7	2·95	7·7	2·80	8·8	2·55	10·8	2·36	2·2	1·65	..	..
45	..	..	..	..	5·4	3·50	6·9	3·1	7·9	2·90	9·2	2·70	11·2	2·45	21·5	1·82	..	..
50	..	..	4·5	3·9	5·5	3·60	7·1	3·2	8·1	3·05	9·4	2·80	11·4	2·58	21·4	2·04	..	..
60	..	..	..	..	5·8	3·90	7·5	3·5	8·5	3·30	9·7	3·10	11·7	2·80	21·4	2·2	..	..
70	..	..	..	..	6·2	4·16	7·8	3·75	8·7	3·55	10·2	3·3	12·0	3·00	21·5	2·4	..	..
80	..	..	..	..	6·5	4·40	8·1	3·95	9·1	3·75	10·5	3·5	12·5	3·2	21·9	2·55	..	..

Table of Kennedy's non-silting Vo Channels N = ·0225—concluded.

Slope.	1 in 2000 or ·5 per 1000		1 in 2500 or ·4 per 1000		1 in 2857 or ·35 per 1000		1 in 3333 or ·30 per 1000		1 in 3571 or ·28 per 1000		1 in 3846 or ·26 per 1000		1 in 4166 or ·28 per 1000		1 in 5000 or ·20 per 1000		1 in 5882 or ·17 per 1000	
Discharge.	Bed width.	Depth.	Bed width.	Depth.	Bed width, W.	Depth, *d*.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.	Bed width.	Depth.
90	..	..	..	..	..	..	8·5	4·15	9·5	3·95	10·9	3·7	13·0	3·4	22·0	2·60	..	..
100	..	..	..	..	..	..	8·6	4·3	9·8	4·1	11·2	3·85	13·0	3·4	22·2	2·70	..	..
120	..	..	..	..	..	..	9·1	4·6	10·2	4·4	11·8	4·15	13·8	3·85	23·0	2·9	..	..
140	..	..	..	..	..	..	9·8	4·95	10·8	4·75	12·2	4·4	14·4	4·1	23·5	3·2	..	..
160	..	..	..	..	..	..	10·1	5·25	11·3	4·95	12·8	4·65	15·0	4·35	24·0	3·4	..	..
180	..	..	..	..	..	..	10·5	5·42	11·8	5·20	13·5	4·90	15·4	4·55	24·8	3·6	..	..
200	..	..	..	..	..	..	11·0	5·65	12·1	5·40	13·8	5·1	16·0	4·80	25·3	3·8	..	..
220	..	..	..	..	..	..	..	..	..	..	14·5	5·3	16·4	5·0	25·8	3·95	..	..
240	..	..	..	..	..	..	..	..	..	..	14·8	5·5	17·0	5·18	26·2	4·10	..	..
260	..	..	..	..	..	..	..	..	..	..	15·1	5·65	17·4	5·30	26·8	4·25	..	..
280	..	..	..	..	..	..	..	..	..	..	15·5	5·90	17·8	5·50	27·2	4·40	..	..
300	..	..	..	..	..	..	..	..	..	..	16·0	6·0	18·2	5·65	27·8	4·55	5·9	3·0
350	..	..	..	..	..	..	..	..	..	..	..	..	19·0	6·0	28·8	4·85	57·5	3·3
400	..	..	..	..	..	..	..	..	..	..	..	..	20·0	6·35	30·0	5·2	56·5	3·65
450	..	..	..	..	..	..	..	..	..	..	..	..	20·8	6·65	30·5	5·4	56·5	3·9
500	..	..	..	..	..	..	..	..	..	..	..	..	21·5	6·90	31·8	5·65	56·7	4·1

550	..	..	..	..	..	..	..	..	..	..	..	..	..	..	33·4	5·9	57·2	4·35
600	..	..	..	..	..	..	..	..	..	..	..	..	..	..	33·8	6·2	58·0	4·35
650	..	..	..	..	..	..	..	..	..	..	..	..	..	..	34·2	6·35	59·0	4·7
700	..	..	..	..	..	..	..	..	..	..	..	..	..	..	34·8	6·55	60·0	4·9
750	..	..	..	..	..	..	..	..	..	..	..	..	..	..	36·0	6·75	60·5	5·05
800	..	..	..	..	..	..	..	..	..	..	..	..	..	..	37·0	6·90	61·5	5·2
850	..	..	..	..	..	..	..	..	..	..	..	..	..	..	37·8	7·1	62·2	5·35
900	..	..	..	..	..	..	..	..	..	..	..	..	..	..	38·2	7·25	63·0	5·5
1000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	39·5	7·555	65·0	5·75
1100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	41·0	7·8	66·5	6·0
1200	..	..	..	..	..	..	..	..	..	..	..	..	..	..	42·0	8·1	68·0	6·45
1300	..	..	..	..	..	..	..	..	..	..	..	..	..	..	43·5	8·35	69·4	6·50
1400	..	..	..	..	..	..	..	..	..	..	..	..	..	..	44·5	8·6	71·0	6·70
1500	..	..	..	..	..	..	..	..	..	..	..	..	..	..	46·0	8·8	72·0	6·95
1600	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	73·5	7·05
1700	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	75·0	7·30
1800	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	76·0	7·40
1900	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	77·8	7·[illegible]
2000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	51·0	9·8	78·5	7·[illegible]
2600	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	86·0	[illegible]
3000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	91·0	[illegible]1
3600	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	98·0	[illegible]·7
4000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	102·0	10·1
4600	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5500	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table showing maximum safe mean velocity in channels.

Material of the channel.	Safe mean velocity in ft. per second.
Light ordinary earth	2·5 to 3
Firm gravel or clay	3·5
Stiff clay	4·0
Broken stone or clay	5·0
Firm conglomerate	6·0 to 7·0
Sound rock	10·0

In most Indian canals the maximum safe mean velocity does not exceed 2½ to 3 feet per second.

Table showing suitable side slopes in various kinds of earth.

Angle of side slope.	Ratio of side slope.	Nature of banks.
° ′		
63 ·20	½ to 1	Alluvial soil, soft rock, firm gravel.
45 ·0	1 to 1	Alluvial soil, stiff earth or clay.
33 ·40	1½ to 1	Ordinary earth.
26 ·30	2 to 1	Loose earth, soft clay.
21 ·48	2½ to 1	Loose earth, soft clay.
18 ·20	3 to 1	Loose earth, soft clay.

Ratio of Bed width to depth

Let b be the bed width and d the depth of water in a canal. Then for a given discharge and given side slopes, there is a ratio of b to d which makes the area of cross section of the canal, and therefore the necessary excavation, a minimum. It is shown in text-books on Hydraulics that if n be the ratio of the side slopes, then the most economical ratio of b to d is as follows :—

n	0	½	1·0	1½	2	2½	3
b	2	1·24	·82	·60	·48	·38	·32

Table of S and $\sqrt{S}$ when S = fall per 1000.

S	$\sqrt{S}$	S	$\sqrt{S}$	S	$\sqrt{S}$	S	$\sqrt{S}$	S	$\sqrt{S}$
·10	·316	·15	·387	·20	·447	·25	·500	·40	·632
·11	·331	·16	·400	·21	·458	·26	·510	·45	·691
·12	·346	·17	·412	·22	·468	·28	·529	·50	·707
·13	·360	·18	·424	·23	·479	·30	·548		
·14	·374	·19	·436	·24	·490	·35	·592		

Table of outlet Discharges.

Note.—One pipe means an Earthen Colaba 0·4 ft. dia.

Its area is 0·125 s. ft. or ⅛th of a s. ft.

Such a pipe is represented by the letter $\overline{\wedge}$.

Orifices of 0·125 s. ft. area are called 1 $\overline{\wedge}$.

Orifices of 0·25 s. ft. area are called 2 $\overline{\wedge}$ and so on.

Pipes.	DIMENSIONS. Area of orifice.	W.	D.	Head in feet = h. ·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0
				Velocity = $5\sqrt{h}$. 1·58	2·23	2·74	3·16	3·53	3·87	4·18	4·47	4·74	5·0	5·24	5·47	5·70	5·91	6·12	6·32	6·51	6·70	6·83	7·07
1	·125	Pipe 0·40 dia.		·2	·3	·35	·40	·45	·50	·50	·60	·6	·6	·7	·7	·7	·75	·75	·8	·8	·85	·85	·90
2	·25	0·5	0·5	·4	·6	·7	·8	·9	1·0	1·0	1·1	1·2	1·3	1·3	1·4	1·45	1·5	1·5	1·6	1·6	1·7	1·7	1·8
3	·375	0·5	0·75	·6	·9	1·0	1·2	1·3	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·2	2·3	2·4	2·4	2·5	2·6	2·6
4	·50	·5	1·0	·8	1·1	1·4	1·6	1·8	2·0	2·1	2·3	2·4	2·5	2·6	2·7	2·9	3·0	3·0	3·1	3·2	3·4	3·4	3·5
5	·62	·62	1·0	1·0	1·14	1·7	2·0	2·2	2·4	2·6	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·8	4·0	4·0	4·2	4·3	4·4
6	·75	·75	1·0	1·1	1·7	2·0	2·3	2·5	2·9	3·1	3·4	3·6	3·7	4·0	4·1	4·3	4·5	4·6	4·7	4·9	5·0	5·2	5·3
7	1·00	·87	1·0	1·4	2·0	2·4	2·7	3·1	3·4	3·7	3·9	4·1	4·9	4·6	4·8	5·0	5·2	5·3	5·6	5·7	5·9	6·0	6·2
8	·875	1·0	1·0	1·6	2·2	2·7	3·2	3·5	3·9	4·2	4·5	4·7	5·0	5·2	5·5	5·7	5·9	6·1	6·3	6·5	6·7	6·9	7·1
9	1·12	1·0	1·12	1·7	2·5	3·0	3·5	4·0	4·3	4·7	5·0	5·3	5·6	6·0	6·1	6·5	6·7	6·9	7·1	7·3	7·6	7·7	8·0
10	1·25 1·	1·0	1·25	1·9	2·8	3·4	3·9	4·4	4·8	5·2	5·6	5·9	6·2	6·6	6·8	7·2	7·4	7·6	7·9	8·1	8·4	8·6	8·8

EXAMPLE.—Supposing an outlet has a head of ·8, and required discharge is 2·8 cusecs; then looking vertically down wards, under head of 0·8 ft. to discharge 2·8 cusecs and in a horizontal line from 2·8: Area of orifice is found to be ·625 orifice of outlet may be ·62 × 1·0, to discharge 2·8 cusecs with a head of ·8 ft.

DESIGN OF WEIRS.

The safety is dependent on the following points :—

1. The weir must be dimensioned to resist the overturning moment of the horizontal water pressure.

2. The thickness, *i.e.* the weight of the apron or floor, must be such that it will be safe from being blown up or fractured by the hydrostatic pressure.

3. The base length (L) must not be less than $C\ H$, the product of the factor C with the head H.

4. The length of masonry apron and its continuation in rip rap or concrete blocks must be sufficient to prevent erosion.

The following values of c have been adopted for specified classes of sand :—

1. River beds of light silt and sand of which 60% passes a 100 mesh sieve, percolation factor $C = 18$.

2. Fine micaceous sand of which 80% of the grain passes a 75 mesh sieve $c = 15$.

3. Coarse grained sand as is found in Central and South India $c = 12$.

4. Boulders or shingles and gravel and sand mixed $c = 9$ to 5.

Thickness of weir :—

$$t = \frac{4}{3}\left(\frac{H - h}{l - 1}\right)$$

Where t = thickness of weir.

H = extreme hydrostatic pressure.

l = specific gravity of masonry.

h = neutralization head.

Length of a fore apron in a weir :—

$$L = 3\sqrt{C}\,H$$

Where L = length of apron.

C and H as before.

FLOORS, THICKNESS AND LENGTH.

I. Of submerged River Weirs on Sand.

A minimum thickness for a floor can be taken as $\sqrt{H}$, *i.e.*, of the maximum statical head which is the height of the weir plus that of the weir shutters. The formula is $t = \frac{4}{3}\ \frac{H-h}{P-1.}$ for submerged aprons or floors, in which H is the maximum statical head and h the loss of head due to percolation up to the beginning of the floor.

The width of submerged river weir aprons or floors on sand foundations is a function not only of the height of the permanent obstruction, *viz.*, that of the masonry weir wall, but also of the quality of the river sand represented by the so termed coefficient c, and is found by the formula $W = 4c\sqrt{\frac{H^a}{13}}$ in which H^a is the height of shutter crest. For example, if H^a be 12 feet and the river coefficient be of class 3, that is if $c = 12$, the width would be $4 \times 12\sqrt{\cdot 93} = 48 \times \cdot 96 = 46$ feet nearly.

II. Canal Falls.

The thickness of the floor of canal falls without a sunk water cushion should be $\sqrt{H+d}$ in which H is the height of the drop wall and d the depth of film, *i.e.* the depth of water above crest. The width of floor should be $2(H+d)$. The same applies to escape falls.

III. Weir Sluices and other partial Regulators on Sand.

The floors of weir sluices are on the same level and subjected to the same hydrostatic pressure as those of river weirs, of which they form an integral part consequently their thickness will be the same as that given to the weir apron.

The head to which a weir sluice is subjected being the same as that on the weir apron, its floor could be made of the same length were it not for kinetic consideration, the rush of water through the sluices being very great; this length may be put down as $2W$, or as $= 8c\sqrt{\frac{H^a}{13}}$.

IV. Head Regulators or Intakes.

The thickness of floor as a minimum should be $\sqrt{H_1}$, H_1 being the height of flood above regulator floor. Thus with flood level 25 feet above regulator floor, the thickness will be 5 feet.

The abolition of water cushions renders it necessary that floors of large falls should be covered by durable stone set in cement mortar. Ashlar, with fine joints is the worst possible for the floor.

Table for Pier Thickness suitable for open Partial Regulators and Weir Sluices.

Span.	THICKNESS FOR DEPTHS OF WATER.			
	15 feet.	20 feet.	25 feet.	30 feet.
10 feet.	2·5	2·7	2·9	3·1
15 feet.	3·6	3·9	4·2	4·5
20 feet.	4·6	5·0	5·4	5·8
25 feet.	5·3	6·0	6·5	7·0

Bligh's Dams and Weirs.

The above table, though purely empirical, will form a useful guide of thickness of Piers in open dams or partial Regulators. For canal heads subjected to a considerable head of water, the thickness of the piers should be 0·4 S. where S=span.

If reinforced, very considerable reduction can be made in the thickness of piers, say ⅔, but for this class of river work a heavy structure is obligatory.

In the Chenab Colony.

1 Square = 25 Killas.

1 Killa : 1·11i Acres.

1 Acre 8 Kanals.

1 Kanal 20 Marlas.

1 Murla = 30¼ Sq. Yards.

In the Montgomery District.

1 Rectangle= 25 Killas

1 Killa = 1 Acre.

Table of areas of square's (Chenab Canals).

Side 1,100 ft. area = 27·77$\dot{7}$ Say 27·80 acres.

No. of squares.	Area acres.	No. of squares.	Area acres.	No. of squares.	Area acres.	No. of squares.	Area acres.
¼	6·9	7·0	194·4	13½	375·0	20·0	555·6
½	13·9	7¼	201·4	13¾	381·9	20¼	562·4
1·0	27·8	7½	208·3	14·0	388·9	20½	569·4
1¼	34·7	7¾	215·3	14¼	395·8	20¾	576·4
1½	41·7	8·0	222·2	14½	402·8	21·0	583·3
1¾	48·6	8¼	229·2	14¾	409·7	21¼	590·3
2·0	55·6	8½	236·1	15·0	416·7	21½	597·2
2¼	62·5	8¾	243·1	15¼	423·6	21¾	604·2
2½	69·4	9·0	250·0	15½	430·6	22·0	611·1
2¾	76·4	9¼	256·9	15¾	437·5	22¼	618·1
3·0	83·4	9½	263·9	16·0	444·4	22½	625·0
3¼	90·3	9¾	270·8	16¼	451·4	22¾	631·3
3½	97·2	10·0	277·8	16½	458·3	23·0	638·9
3¾	104·2	10¼	284·7	16¾	465·3	23¼	645·8
4·0	111·1	10½	291·7	17·0	472·2	23½	652·8
4¼	118·0	10¾	298·6	17¼	479·2	23¾	659·7
4½	125·0	11·0	305·6	17½	486·1	24·0	666·7
4¾	131·9	11¼	312·5	17¾	493·1	24¼	673·6
5·0	138·9	11½	319·4	18·0	500·0	24½	680·6
5¼	145·8	11¾	326·4	18¼	506·9	24¾	687·4
5½	152·8	12·0	333·3	18½	513·9	25·0	694·4
5¾	159·7	12¼	340·3	18¾	520·8		..
6·0	166·7	12½	347·2	19·0	527·8	..	..
6¼	173·6	12¾	354·2	19¼	534·7	..	..
6½	180·6	13·0	361·1	19½	541·7	..	..
6¾	187·5	13¼	368·1	19¾	548·6	..	..

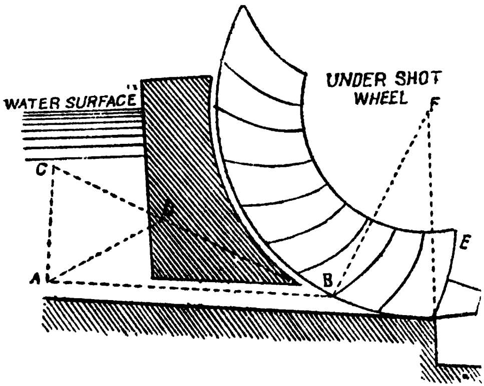
Table showing cost of the principal canal systems in the Punjab up to 1925.

Canals.	Discharge maximum.	Cost of main canals.	Length in miles.		Gross area commanded in acres.	Area irrigated in acres.	Cost per irrigated acre.
			Main.	Distributaries.			Rs.
1. Western Jumna Canal	6,430	1,79,36,355	299	1,747	2,734,024	741,914	24·0
2. Sirhind Canal ..	8,828	2,50,02,707	318	1,645	4,400,000	1,605,211	16·0
3. Upper Bari Doab Canal ..	6,700	2,07,04,368	324	1,560	1,639,499	1,194,606	19·0
4. Lower Bari Doab Canal ..	7,000	2,14,16,953	132	1,228	1,748,752	1,159,745	19·0
5. Upper Chenab Canal	12,880	3,57,11,891	173	1,262	1,577,010	536,712	68·0
6. Lower Chenab Canal	10,184	3,37,79,061	427	2,250	3,390,831	2,436,385	14·0
7. Upper Jhelum Canal	8,250	4,32,56,441	128	666	603,740	304,723	140·0
8. Lower Jhelum Canal	4,320	1,84,22,830	181	993	1,337,905	845,506	23·0
9. Sidhnai Canals ..	2,437	12,92,316	68	249	419,848	324,069	4·00

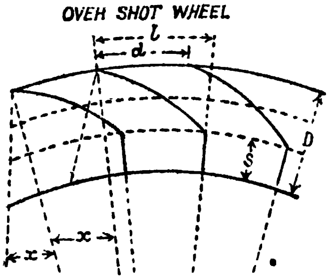
THE DEVELOPMENT OF WATER POWER.

WATER-WHEELS.

Undershot Wheel.—Float boards radial or inclined 20° towards current. When not used in tidal streams, breadth may equal or exceed diameter maximum efficiency when velocity of wheel equals half velocity of stream. Usual efficiency = ·28



Breast Wheel.—Floats surrounded or covered at the sides and curved to form buckets. Breast work of masonry built up round wheel as high as centre line. Streams led down a masonry slope to act on wheel by momentum and gravity. Suited for moderate supply of water and fall of 6 to 8 ft. Usual efficiency = ·44.



Overshot Wheel.—Floats formed into buckets. Water led in trough to top of wheel. Ratio of width to diameter usually small. Requires less water to drive it than the other forms and is more than twice the power of undershot wheel of same size. Fall must not be less than the diameter of wheel.

D = depth of shrouding.
d = distance of buckets apart at periphery.
s = length of start (Radial).

x = angle of radius of bucket curve with radial line of wheel at points of bucket = 15° in Overshot or Breast wheels.

l = 1¼ D in large wheels.

= D in wheels under 25 ft. diameter.

Usual efficiency = ·55.

Advantages of Turbines over Water Wheels.

The water wheels have been superseded by the turbines because—

1. The latter occupies small space.
2. The higher speed may be obtained.
3. A wider choice in speed is possible.
4. It can be used under a wider range of head, whereas the head for an overshot wheel should be only a little more than the diameter of the wheel.
5. A greater capacity may be obtained without excessive size.
6. It can work submerged.
7. There is less trouble with ice.
8. It is usually cheaper.

Advantages of Water Wheels over Turbines.

For small plants the turbine is often poorly designed, cheaply made, unwisely selected and improperly set. It may thus be very inefficient and unsatisfactory. In such cases an overshot water wheel may be better. The latter has a very high efficiency when the water supply is much less than its normal value. It is adopted for heads from 10 to 40 ft. and from quantities of water from 2 to 30 cusecs.

An overshot wheel on the Isles of Man is 72 ft. in diameter and develops 150 H. P. Another in Troy in New York is 62 ft. in diameter, 22 ft. wide, weighs 230 tons and develops 550 H. P.

Essentials of Water Power Plant.

A water power plant requires some or all of the following:—

A dam which may create most of the head available for the plant or it may merely create a small portion of it and be erected primarily to provide a reservoir and to furnish a suitable intake for a pipe line. The body of water is called the head water (for construction of dam see page 492).

The water may be conducted from the head water to the turbines by means of an open channel called a canal or flume or by means of a closed pipe under pressure which is called a penstock.

Racks and screens are usually employed at the intake to the flume or penstock to keep rubbish being carried down to the wheels. The water at this point may be shut off by means of head gates.

The turbines with its case or pits and draft tube, if any, comprise the setting. The body of water that the turbine discharges into is called tail water. The channel conducting the water away is the Tail Race.

Classification of Turbines.

Turbines are classified according to—

1. Action of water—
   (a) Impulse (or pressureless).
   (b) Reaction (or pressu .).

2. Direction of Flow—
   (a) Radial outward.
   (b) Radial inward.
   (c) Axial (or parallel).
   (d) Mixed.
3. Position of Shaft—
   (a) Vertical.
   (b) Horizontal.

Action of Water.—The *Impulse turbine* is a pressureless turbine (Tangential wheel or Pelton type) in which the head is converted into velocity and water acts on buckets on the periphery. The wheel is never filled with water.

Reaction Type.—In this type all the passages are filled with water under variable pressure throughout the flow.

Position of Shaft.—The horizontal shaft is more desirable on account of greater accessibility and less trouble. A vertical shaft turbine occupies less flow space, but often requires more excavation and a deeper building. The vertical shaft turbine is used where it is necessary to set the turbine down by the water while the generator or other machinery that it drives must be above.

Draft Tube.—Occasionally reaction turbines have been set so as to discharge above tail water, in such cases the fall from the point of discharge water was lost. To avoid this loss turbines have been submerged below tail water level. By the use of draft tube it is possible to set the turbine above tail water without suffering any loss of head.

The tangential water wheel is best adopted for high heads and relatively small quantities of water. By that is meant that the choice of the type is a junction of the capacity as well as the head. The efficiency of tangential water wheels are obtained due to poor designs.

Heads as high as 5,412 ft. have been used in Switzerland, developing 15,000 H. P. though in majority of cases the head is below 1,000 ft. The Mashobra power house in Kashmir is of this type.

The reaction turbine is adopted for low heads or a relatively large quantities of water. Reaction turbines are used under heads as low as 16 inches, though 4 to 5 ft. is usual for economical working (below which the Undershot water wheel or Breast wheel is better suited). The highest head employed for a reaction turbine is 670 ft., developing 6,000 H. P. at 514 Revolutions per minute. The largest unit so far develops 25,000 H. P. The power of the turbine depends not only on its size but also upon the head under which it operates. The turbine mentioned is the most powerful but not the largest in point of size. The largest turbine is of 10,000 H. P. The diameter of the runner is about 16 ft. and the height 12 ft. and the weight about 144,000 lbs. The total weight of the rotating parts including the generator is 550,000 lbs. The average head is 30 ft. and the speed 577 Revolutions per minute. This last case is of vertical shaft.

The smallest head under which a turbine of any size is working in India is 5½ ft. at Renala, developed by Sir Ganga Ram. The output is 200 B. H. P.

The efficiency from average turbines is 80 to 85%. For large capacities and under favourable condition up to 90 per cent. may be obtained. For small power under unfavourable conditions hardly 75% or less is obtained.

General Laws of Constants.

$$Q = c\sqrt{2gh.}$$

Where Q = discharge through an orifice in cusecs.

c = a constant.

h = The head in ft.

$\therefore$ discharge varies as $\sqrt{h.}$

Since the power of each unit volume of water varies as the head and since the amount of water discharged varies as the square root of the head $\sqrt{h,}$ it must be true that the power in-put of given turbine under variable head varies as the three half powers of the head. $h^{\frac{3}{2}} = h \times \sqrt{h.}$

It is customary usually to rate the turbine on a 1 foot fall bases and accordingly the out-put at head required can be determined as follows :—

$$N = N_1 \sqrt{h.}$$

$$Q = Q_1 \sqrt{h.}$$

$$H.\ P. = (H.\ P.)_1 \times h^{\frac{3}{2}}$$

Specific Speed.—In order to establish a relation between the out-put head, speed, a special commercial term has been evolved and is known as specific speed. This takes into account all constants and is expressed by the following formula :—

$$N_s = \frac{N\sqrt{H.\ P.}}{h^{\frac{5}{4}}} \left\{ \text{Note } h^{\frac{5}{4}} = h \times \sqrt{\sqrt{h}} \right.$$

This expression is very useful and is briefly stated that in a turbine run under 1 foot head the diameter was such as to produce 1 H. P. the N will equal N_s. This will at once show to what class the turbine belongs. Some manufacturers denote this symbol N_s as N_u, K_t and numerous others.

As stated above this expression takes in to account all variable and constants including the efficiency and gives power expected under various heads, also the speed at which it will run.

The usual value of N_s for a tangential water wheel is from 3·5 to 5. This may run as high as 5 or 6, though the latter involves some sacrifice of efficiency. With the reaction turbine the minimum value of N_s that has been attained is 10, while the maximum value is 100. Usually it is between 20 or 30 and up to about 85.

Selection of Turbine.

Before starting any calculations it is best to determine the value of N_s. This can be easily done, as in all problems the head is known, also the power required, and for the speed that will be determined by the type of machinery is to be run with it. Hence it is an easy matter to determine the specific speeds. As soon as the specific speed is determined this will automatically determine the type required.

Illustrations.—For a turbine of 2,000 H. P. @ 1,000 Revolutions per minute under 1,600 ft. head, the values of N_s = 4·42. Thus a very low speed turbine, the tangential water wheel is required. The actual Revolution per minute however is high.

For a 5,000 H. P. turbine at 100 R. P. M. under 30 ft. head N_s = 80·3. Thus a high speed reaction turbine is indicated, though the actual R. P. M. may be relatively low.

Suppose a 12 H. P. turbine is to run at 100 R. P. M. under 36 ft. head. The value of specific speed is 3·95, which means tangential water wheel is required. For the larger power under same conditions in the preceding example, a reaction turbine was required. If the speed in this case were 600 R. P. M., a low speed reaction turbine would be necessary; N_s would equal 23·6.

Suppose that a 20 H. P. turbine is to run at 300 R. P. M. under a 60 ft. head, the value of N_s is 8·04 and that would require a tangential water wheel with two nozzles (*i.e.* 4·02 N_s per nozzle).

If a 10,000 H. P. is required at 300 R. P. M. under a 60 ft. head the value of N_s would be 179·5. As this is an impossible value, it would be necessary to reduce the speed or to divide the power up among at least 4 units of 2,500 each. This can also be accomplished by mounting all these units on one shaft and have a turbine of 4 runner on shaft, so that the electrical or other machinery is driven from one shaft.

Possible Choice.—It has been shown that if the speed and power under a given head are fixed, the type of turbine necessary is determined. It may be possible to vary the specific speed through a considerable range of values. Now suppose the speed is fixed, the power such as 20,000 H. P. may be developed in a single unit, in two units of 10,000 H. P. each or 8 units of 2,500 H. P. each. For all then we have different types of runners required. Where both the speed and power are changeable then the choice becomes very wide.

As an example 500 H. P. may be required under 140 ft. head. Suppose this power be divided up in two runners and the speed to be 120 R. P. M. The value of N_s is then 4·12 which shows that is double overshot tangential water which is required or the power developed in a single runner at 600 R. P. M., the value of N_s would be 29·2 which would call for a reaction turbine.

It is customary to choose a speed between certain limits as neither very low nor very high speed is desirable. Also the number of units into which a given power is divided is limited.

General Formula. (*Moles worth*),

r = Radius at entrance in ft.

R = „ „ exit in ft.

α = Guide angle.

β = Entrance angle.

γ = Exit angle.

$\rho = \frac{R}{r}$ Usually = 1·2 in outward; = ·83 in inward.

Q = c. ft. of water per second

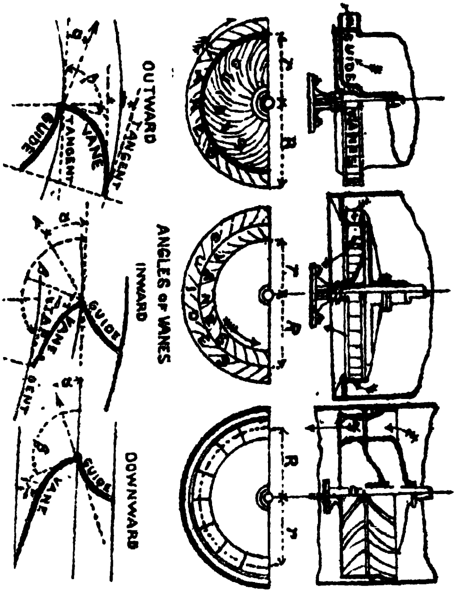
H = head of water in ft.

V = velocity of water at guides due to the head in ft. per second = ·95 theoretical velocity due to head $= 7{\cdot}62\sqrt{H}$.

v = velocity of periphery of turbine at entrance = ·6 V usually.

n = number of vanes.

= number of guides.



The Development of Water Power.

Useful Data :—(Approx).

1. *Flow.*

1 cusec flow = 1 c. ft. per second = 62·4 lbs. per second.
= 60 c. ft. per minute = 3,744 lbs. per minute.
= 374 gallons per minute.
= 3,600 c. ft. per hour.
= 86,400 c. ft. per day.
= 2·6 million c. ft. per month.
= 31½ million c. ft. per year.

Gallons per minute = cusecs × 374.

$$\text{Cusecs} = \frac{\text{gallons per minute.}}{374}$$

2. *Regulating Storage.*

100,000 c. ft. stored will give	1·16 cusecs	for 24 hours.
,, ,, ,, ,, ,,	2¼ ,,	,, 12 hours.
,, ,, ,, ,, ,,	4½ ,,	,, 6 hours.
,, ,, ,, ,, ,,	9¼ ,,	,, 3 hours.
,, ,, ,, ,, ,,	27¾ ,,	,, 1 hour.

3. *Main Storage.*

31½ million c. ft. stored is equivalent to 1 cusec for a year ; but owing to evaporation and percolation more storage would actually be required.

1,000 million c. ft. stored will give	30 cusecs	for a year.
,, ,, ,, ,, ,,	40 ,,	,, 9 months.
,, ,, ,, ,, ,,	60 ,,	,, 6 months.
,, ,, ,, ,, ,,	90 ,,	,, 4 months.
,, ,, ,, ,, ,,	120 ,,	,, 3 months.

4. *Reservoirs.*

1 acre = 43,560 sq. ft.

1 acre of water 1 ft. deep = 43,560 c. ft. = 1 acre ft.

1 square mile = 640 acres = 27·88 million sq. ft.

1 sq. mile of water 1 foot deep = 1 square mile foot = 27·88 million c. ft., which will (in practice) give a flow of about ¾ cusec for 12 months, 2¼ cusecs per 4 months, or 3 cusecs for 3 months.

Power from flow.

$$\text{Horse power} = \frac{Q \times F \times W}{550}$$

$$= \frac{Q \times F}{8 \cdot 8} \quad \text{(Theoretical H. P.)}$$

Where Q = discharge in c. ft. per second.

W = weight of one c. ft. of water = 62·5 lbs.

F = net fall of water in ft.

For all practical purposes use the following ;—

(*a*) for larger schemes H. P. $= \frac{Q\,F}{11}$, this gives an efficiency of 80%

(*b*) for small projects H. P. $= \frac{Q \times F.}{15}$, this gives an efficiency of 60%.

Power from Storage.

(*a*) Regulating of storage $= \dfrac{\textit{Thousands c. ft. stored} \times \textit{head in ft.}}{42.}$

= electric H. P. hours.

If the divisor is 56, the result is in K. W. hours or B. O. T. Units.

(*b*) Main $= \dfrac{\textit{Millions c. ft. stored} \times \textit{head in ft.}}{370}$

= electric H. P. years.

If the divisor is 500, the result is in K. W. years.

Millions c. ft. $\times$ head in ft. $\times$ 17 = B. O. T. Units.

ADMISSIBLE COST OF HYDRAULIC DEVELOPMENT (APPROX.).

Assume that 10,000 electric H. P. is required for use in a certain district and that the alternatives are steam and water power. Two cases may be assumed, *i.e.*, water power on the spot, transmission of 50 miles. As regards fuel three prices have been taken, *i.e.*, Rs. 8, Rs. 10 and Rs. 24 per ton. Four characteristic load factors will also be taken, *i. e.*, 20%, 40%, 60% and 80% with modern boilers and steam turbines, using good coal, an average consumption of $1\frac{1}{2}$ lbs. per electric H. P. hours generated may be taken. Allow 10% for interest and depreciation. Divide the figures in column by 10,000 which gives this as the permissible capital cost per electric H. P. installed when there is no transmission. Next assume a transmission of 50 miles with 10% loss of power. The cost of transmission line is Rs. 10,000 per mile. But to deliver 10,000 electric H. P. while losing 10% the plant must be of 11,200 electric H. P. and an extra capital cost of this at Rs. 100 per electric H. P. (1·2 lakhs) is further deducted in column 7. The values so obtained, divided by 11,200 give the permissible cost of the hydraulic development per electric H. P. installed in column 8.

ADMISSIBLE COST OF HYDRAULIC DEVELOPMENT (APPROX.).

Load Factor.	Cost of fuel per ton.	Cost of fuel per annum.	Capitalized value at 10 %.	WATER POWER AT SITE NO TRANSMISSION. Admissible capital cost by hydraulic development only per electric H. P. installed 10,000 electric H. P.	TRANSMISSION 50 MILES. Column 4 less 5 lakhs for cost of transmission.	TRANSMISSION 50 MILES. Column 6 less 1·2 lakhs cost of additional plant for transmission losses.	TRANSMISSION 50 MILES. Admissible cost of hydraulic development only per electric H. P. installed 11,200 electric H. P.	REMARKS.
%	Rs.	Lakhs.	Lakhs.	Rs.	Lakhs.	Lakhs.	Rs.	
1	2	3	4	5	6	7	8	
20	8	1·06	10·6	106	5·6	4·4	39	Other things being equal, fuel has an advantage when the plant is not fully loaded most of the time, *i.e.*, when the load factor is bad, while on an exceptionally good load factor, water power has an immense advantage.
	16	2·12	21·2	212	16·2	15·0	134	
	24	3·18	31·8	318	26·2	25·0	223	
40	8	2·12	21·2	212	16·2	15·0	134	
	16	4·20	42·4	424	37·4	36·2	322	
	24	6 36	63·6	636	58·6	57·2	511	
60	8	3·18	31·8	318	26·2	25·0	223	
	16	6·36	63·6	636	58·6	57·4	511	
	24	9·54	95·4	954	90·4	89·2	795	
80	8	4·24	42·4	424	37·4	36·2	322	
	16	8·48	84·8	848	79·8	78·6	700	
	24	12·72	1,27·2	1272	122·2	121·0	1,008	

Limits of cost of existing Hydro-Electric plants in India.

	Per E. H. P. Installed. Rs.	Per K. W. Installed. Rs.
Maximum	1,170	1,560
Minimum	179	240
Mean	674	900

THE PUNJAB HYDRO-ELECTRIC WORKS.

Undertaking.	Amritsar H. E. Pumping Installation.	New Egerton Woollen Mills.	Simla Municipal Electric Department.	Sir Ganga Ram Hydro-Electric Works.
Location ..	Near Amritsar.	Dhariwal.	Chaba near Simla	Renala Khurd.
Source of water ..	Main Branch Lower, Upper Bari Doab Canal, Grand Trunk Rapid.	Fall in Upper Bari Doab Canal.	Nante khad, Tributary of Sutlej.	Fall in Lower Bari Doab Canal.
Minimum perennial flow, cusecs.	1,050	200 (generally 500-600)	19	2,000 general (5,000 c. ft.)
Regulating storage c. ft.	*Nil*	*Nil*	642,000	,,
Working head ft.	5 to 9·8	,,	540	8 to 10 ft.
Length of open channel	Short diversion.	,,	$2\frac{1}{4}$ miles	Short diversion.
Capacity of channel ..	2,300	..	35	..
Length of pipe line ..	Open penstock.	Open penstock.	1,300	..
Plant Installed K. W ..	525	670	1,750	1,100 at P. F. ·8.
Ultimate capacity of site K W. ..	525	670	685 on minimum flow.	1,375
Transmission Line ..	..	..	..	26 miles, size of wire 3 to 8 S. W. G.

JAMMU AND KASHMIR HYDRO-ELECTRIC WORKS.

Undertaking.	Jummu Power Installation.	Jhelum River.
Location ..	Jammu, Tawi.	Mohora, Kashmir Road.
Source of water ..	Ranbir Canal.	Rapids in Jhelum.
Minimum perennial flow, cusecs	500	4,000
Storage ..	*Nil.*	*Nil.*
Working head in ft. ..	25	390
Length of open channel ..	*Nil.*	6¼ miles.
Capacity of channel's cusecs ..	..	560
Length of pipe line in ft. ..	*Nil* open stock.	750
Plant installed K. W. ..	670	4,000
Ultimate capacity continuous power K. W.	830	105,000 on minimum flow and 14,500 on present open channel

UNITED PROVINCES HYDRO-ELECTRIC WORKS.

Undertaking.	Ganges Head Works Supply.	Mussoorie-Dehra Municipal H.E.Scheme
Location	Bahadrabad	3 miles from Mussoorie.
Source of water ..	Two falls in the Ganges Canal.	Two hill streams.
Minimum perenial flow ..	3,000	8
Working head ..	19	1,000
Length of open channel ..	Short diversion.	*Nil*
Length of pipe line ..	*Nil.*	4,350
Plant installed K. W. ..	450	1,790
Ultimate capacity of site ..	3,800	530 on minimum flow.

BOMBAY HYDRO-ELECTRIC WORKS.

Undertaking.	Andhra Valley.	Bhatghar.	Gokak Mills Co.	Tata H. E. P. S. Coy.
Location	Western Ghats near Poona.	32 miles from Poona, 3 miles from Bhat.	Gokak W. Ghats.	Lonavla W. Ghats.
Source of supply ..	Andhra Lake.	Lake Whiting.	Ghatapreba River.	Shirwata, Walwhar and Lonavla Lakes.
Minimum perennial flow, cusecs.	Storage alone.	150 (from storage)	136	Storage alone.
Main storage in c.ft. ..	12,000	5,312	*Nil.*	9,938
Regulating storage in c.ft	*Nil.*	*Nil.*	1,100	2·7 indirect and forebay.
Working head in ft. ..	1,743	46 to 101	210	1,725
Length of open channels in ft.	Tunnel 1·65 by 82·8 s.ft.	*Nil.*	½	4·6
Capacity of channel's cusecs.	600	..	200	480
Length of pipe line in ft.	4,700	440	275	13,000
Plant installed K. W. ..	50,000	1,024	1,570	50,000

SANITARY ENGINEERING.

WATER WORKS.

As soon as the daily consumption per head and the population of a town is known we proceed to design the following:—

Storage Reservoirs.

Before constructing a storage reservoir, it is necessary to ascertain the probable available rainfall of the catchment area of the reservoir contemplated. From this the daily supply in gallons G can be found by the formula.

$$G = 62{\cdot}15\ A\ (\tfrac{1}{3}R - E.)\ *$$

where A=area in acres.
R=mean rainfall in inches, and
E=loss by evaporation, percolation, etc.

A more reliable method is to gauge the discharge of the stream.

Hawkesley's rule for storage:—

F=mean annual rainfall in inches of three consecutive dry years say $\frac{5}{6}$ of average rainfall.

$$D = \text{number of day's supply to be stored} = \frac{1{,}000}{\sqrt{F}}$$

Storage reservoirs are formed by means of dams constructed across valleys. The types of dams generally used are—

(*i*) Earthen dams; and
(*ii*) Masonry dams.

(*i*) ***Earthen dams***:—

For dams of height between 50 and 75 feet.

Crest of dam =6 to 7 feet above the high water level.
Width at top = 10 to 20 feet.
Upstream slope =3 to 1.
Downstream slope=2 to 1.

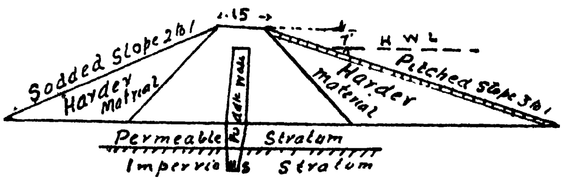
For low dams, *i.e.*, 15 feet high and under:—

Crest of dam =4 to 5 feet.
Width at top =7 to 10 feet.
Upstream slope =2 to 1.
Downstream slope=$1\frac{1}{2}$ to 1.

For dams of height between 15 and 50 feet the dimensions may be intermediate between the foregoing; and

For dams above 75 feet height the embankment should be reinforced by adding dry stone toes to the slopes.

EARTHEN DAM WITH CENTRAL PUDDLE CORE.



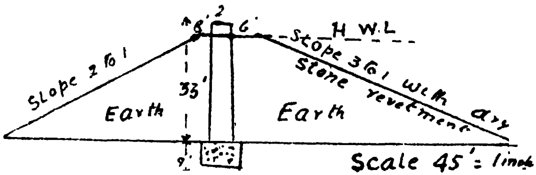
* "Water Supply" W. Pole, page 44.

Where earth slopes are liable to damage by wave action, reinforced concrete is a good protection.

Earthen dams with masonry core walls :—

In earthen dams with puddle surface, the puddle is liable to slide and crack when the water level in the reservoir is low or the embankment settles, and hence it is no longer water-tight. The puddle core is better. But with masonry core wall this argument does not apply and the upstream half of the dam only serves to support the wall when the reservoir is empty.

KAIR TANK DAM



Masonry core wall cannot be built except on concrete foundations, it is better to substitute a masonry dam.

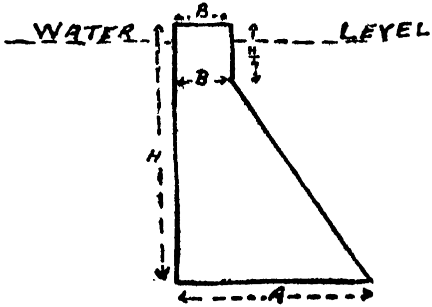
(ii) *Masonry dams*—

(*a*) Low masonry dams :—

H = height of dam at water level.

A = width of base of dam.

B = width at top and at $\frac{H}{4}$



W = weight of masonry per cubic feet.

If W =	.. 120	130	140	150	lbs. per c. ft.
Then B =	.. ·18H	·175H	·17H	·165H	
and A =	.. ·72H	·70H	·68H	·66H	

(*b*) High masonry dams:—

H = height of dam in feet.

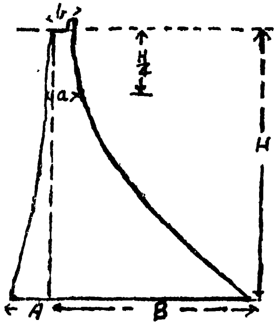
b = width of dam at water level.

a = width of dam at $\frac{H}{4}$

A = offset on upstream.

B = offset on downstream.

P = maximum pressure in masonry in tons per square foot.



Then $B = \sqrt{\frac{\cdot05H^3}{P + \cdot03H}}$ and $A = \left(\frac{\cdot09H}{P}\right)^4$

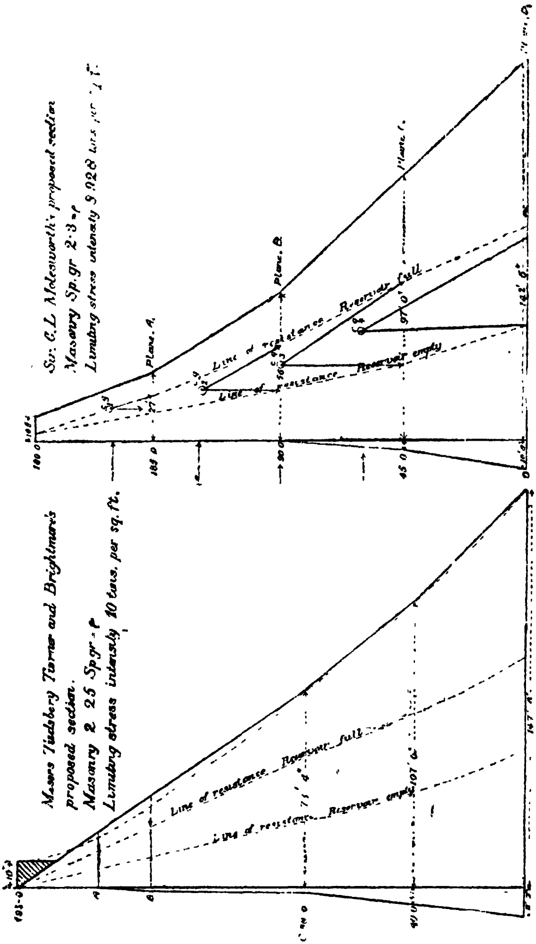
But the minimum value of B should in no case be less than ·6H.

To keep the resultant within the middle third $B = \frac{H}{\sqrt{S}}$, S being the specific gravity of masonry.

Rubble masonry is in all cases preferable to regularly coursed masonry for dams as the irregularity of joints gives a better protection against leaks. The stones should be carefully dressed and laid in cement. All spaces should be filled with stones no matter how small, and no grouting should be allowed under any circumstances.

The intensity of pressure on the inner face with the reservoir empty and on the outer face when full shall at no point exceed the safe limit, *i.e.*, 9 tons per sq. ft. on the inner side and 7 tons per sq. ft. on the outer face. Tension on the face must be inner, avoided at all costs by the line of resistance falling in the middle third of the base and all sections.

A slight curvature in plan without being considered as allowing the dam to depart from a true gravity dam is an advantage.


Sir G.L. Molesworth's proposed section
Masonry Sp.gr 2·3
Plane A.
Plane B.
Line of resistance Reservoir full
Line of resistance Reservoir empty
Messrs Tudsbery Turner and Brightmore's proposed section.
Masonry 2 25 Sp gr.
Limiting stress intensity 10 tons, per sq. ft.
Line of resistance Reservoir full
Line of resistance Reservoir empty

2. *Settling Tanks.*

The heavy matters in suspension are got rid of by means of settling tanks and only lighter and finer particles are removed by filtration.

Method of working:—The systems in use are:—

(*i*) Intermittent system.

(*ii*) Continuous system.

(*i*) In the intermittent system the bottom of the settling basins must be at a higher level than the filter beds, involving an increased lift for the pumps. Besides, this system requires more basins, *i.e.*, they are designed for 25% in excess, to allow for cleaning the sediments.

(*ii*) In the continuous system larger quantity of water can be cleaned in a given time and only requires the overflowing top water level to be a little higher than the filter beds to provide the flow to them by gravitation; but it is essential that the settling tanks should be made in a series of long, narrow sections.

3. *Filters.*

The finer particles of matter still remaining in suspension are removed by means of filters.

Slow Filtration through sand:—

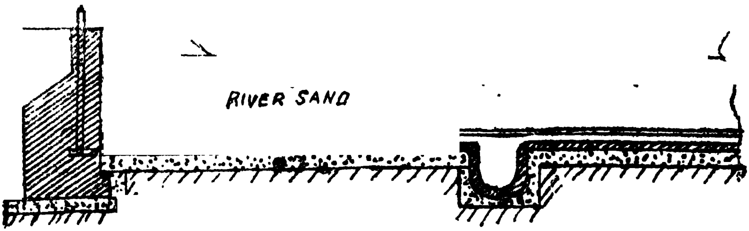
The sand filter beds are made of moderate size, having a water-tight bottom of impermeable soil puddled clay, concrete or brickwork and generally left open at the top. The filter beds consist of a bed of sand at the top, resting upon a layer of coarse sand or fine gravel, supported by a layer of coarse gravel or small stones, which is underlaid by rubble stone, or two or more courses of bricks laid dry with intervals between them. A satisfactory and inexpensive method is to cover the floor with transverse rows of bricks laid dry end to end with a space of 4½" between each row. These are then completely covered with bricks laid dry at right angles to the rows. A series of 4½" channels are formed.

A new filter is pervious to bacteria until a film of slime forms on the surface.

The head should not exceed 3 feet, although maximum upto 6 feet has been used in U. S. A. with satisfactory results.

Allow 1 square foot of filter for each 1 to 2 gallons per hour, with due allowance of spare units for cleaning, etc.

Filter Calcutta Water Works.



The clear water wells should be of sufficient capacity to equalise the demand. say 2 to 3 hours supply.

4. *Collecting Reservoirs.*

The water is conveyed from the filters to the collecting tanks by means of pipes. They are generally formed by excavating them in the ground. The most economical method consists in partially excavating them and employing the excavated material to form embankment for enclosing the upper portion of the reservoir. A plan of a collecting reservoir is given on page 769, Part II.

The water is then pumped to Service Reservoirs for distribution through C. I. mains.

Service tanks should be capable of holding 3 days supply.

Use of water tower.—If the source is below the level of the main service reservoir the water must be pumped through a rising main. If any high ground exists near the source, it is sometimes preferable to pump to a water tower and gravitate thence to the main service reservoir rather than pump the whole distance.

Supplies off rising main should be avoided. To reduce the friction and the work done by the pumps, the rising main should be straight and where bends are necessary they should be as slight as possible. 90° or 45° bends should be avoided. 45° branches can be used instead of Tees.

Hardness of Water.

When a water contains in solution one part by weight of lime or other equivalent hardening salt in 100,000 parts of water, it is said to possess 1° of hardness.

Water of less than 6° of hardness softens lead to an extent and is dangerous to health if used for domestic purposes.

Water is said to be hard when it contains more than 7 grains of dissolved mineral matter per gallon.

Carbonate of lime produces temporary hardness in water and sulphate of lime produces permanent hardness.

Parts carbonate lime per 100,000 water $\times \frac{7}{10}$ =grains per imperial gallon or degrees of hardness on Clark's Scale.

Standard of Purity.

Total hardness in practice varies from 0 to 30 degrees; 5 degrees is generally considered best. Water containing more than the following quantities of impurities per 100,000 should be looked upon with suspicion:—

Chlorine 1 part Nitrites 0·2 part Nitrates 0·3 parts.
Ammonia 0·1 part Organic Carbon 2 parts Organic Nitrogen 3 parts and Albumenoid Ammonia 0·01 part.

Test of Water.

Simple and ready tests for rough analysis:—

Sewage.—Four drops of a solution of potash (Conely's Fluid) to a small glass of water, the colour turns pale or yellow if decomposed organic matter is present.

Lead.—Six drops of sulphuric acid in a small glass of water, white precipitate will be found if lead is present.

Zinc.—Six drops of ferro-cyanid of potassium to small glass of water will turn it green if zinc is present.

Copper.—Eight drops of ammonia in a small glass of water, water turns blue if copper is present.

Purification of water by Calcium Hypochlorite (or Chlorine).

If the crude water is fairly free from suspended matter of an organic nature 1 part of chlorine per 1,000,000 serves to destroy all germs. It has been proved in laboratory that 10 to 15 drops of chlorine water, stirred into a tumbler full of water will extinguish every trace of life. Prefiltration is necessary when the organic matter is in suspension. If it be in solution and irremovable by coagulent then more chlorine must be added. The addition of 1·1 gram per gallon of the chemical at the pumping station reduces the bacteria by 99·8 %.

The following should be carefully noted in connection with pipes for water works:—

(*i*) Discharge should be in gallons per minute.

(*ii*) Diameter of pipe should be taken as internal dia, and should be in ins.

(*iii*) Length of pipe should be in feet.

(*iv*) Head of water should also be in feet.

$$H=\frac{G^2\times L}{729\ D^2}$$

Where G = Discharge in gallons per minute.

D = Diameter in inches.

L = Length in feet.

H = Head in feet.

Example.—It is required to find the head for a discharge of 300 gallons per minute through a 3″ pipe for a pipe length of 1037 feet.

The following tables give ·3762 feet head for 100 feet length

$$\therefore \text{Total head for } 1037 \text{ ft} = \frac{1037\times \cdot 3762}{100} = 3\cdot 901 \text{ feet.}$$

For discharges not given in the table the answer will be in proportion of their squares. Thus, if the discharge is 320 gallons then head $=\frac{(320)^2\times 3\cdot 901}{(300)^2}$ or 4·438 feet.

In fixing the diameter of pipes for supplying cities, it is necessary to bear in mind the maximum hourly demand of water, for domestic purposes may become 3 times the average hourly demand. Again, during summer months much more water is used than in winter and this necessitates still larger diameter.

Water Works Table.

D. or Diam. of pipe in inches.	G. or Gallons per minute.										
	¼	½	¾	1	1¼	1½	1¾	2	2½	3	3½
	H. or Head used in a pipe for 100 lineal feet.										
Inches.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
½	·2743	1·097	2·469	4·389	6·862	9·875	13·44	17·56	26·83	39·51	53·75
¾	·0360	·1440	·325	·578	·903	1·300	1·774	2·312	3·540	5·202	7·080
1	·0085	·0342	·077	·1368	·2138	·308	·4199	·5472	·8552	1·232	3·280
1¼	·0028	·0112	·025	·0449	·0699	·1010	·1375	·1796	·2796	·4041	·5500
1½	·0011	·0044	·010	·0181	·0281	·0407	·0551	·0724	·1120	·1629	·2217
1¾	·0005	·0020	·0046	·0083	·0129	·0187	·0254	·0332	·0508	·0747	·1017
2	..	·0003	·0029	·0043	·0067	·0097	·0133	·0171	·0269	·0386	·0527
2½	..	..	·0008	·0014	·0022	·0031	·0043	·0056	·0087	·0124	·0172
3	..	..	..	·0005	·0008	·0012	·0017	·0022	·0031	·0051	·0069
4	..	..	..	..	..	..	..	·0005	·0008	·0012	·0016
5	..	..	..	..	..	..	..	..	..	·0004	·0005

D. or Diam. of pipe in inches.	G. or Gallons per minute.										
	4	5	6	7	8	9	10	11	12	13	14
	H. or Head used in a pipe per 100 lineal feet.										
Inches.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
1	2·193	3·426	..	..	..	..	..	..	..	..	..
1¼	·718	1·100	..	..	..	..	..	..	..	..	..
1½	·289	·4513	..	..	..	..	..	..	..	..	..
1¾	·1328	·2032	..	..	..	..	..	..	..	..	..
2	·0683	·107	·1543	·2100	·2733	·3470	·4282	·5187	·6173	·7245	·8403
3	·0090	·0121	·0203	·0477	·0360	·0473	·0564	·0682	·0812	·0953	·1105
4	·0021	·0032	·0046	·0067	·0083	·0107	·0134	·0162	·0193	·0226	·0268
5	·0007	·0011	·0015	·0022	·0027	·0035	·0043	·0052	·0061	·0073	·0084
6	·0003	·0004	·0006	·0009	·0010	·0014	·0017	·0020	·0024	·0029	·0033
7	·0001	·0002	·0004	·0004	·0005	·0007	·0008	·0010	·0011	·0014	·0016
8	..	..	·0002	·0002	·0003	·0004	·0004	·0005	·0007	·0007	·0008
9	..	..	..	·0001	·0001	·0001	·0002	·0002	·0003	·0003	·0004
10	..	..	..	..	..	..	·0001	·0001	·0001	·0002	·0002
11	..	..	..	.	..	..	..	..	..	·0001	·0001

Water Works Table.—contd.

D. or Diam. of pipe in inches.	G. or Gallons per minute.										
	15	16	17	18	19	20	21	22	23	24	25
	H. or Head used in a pipe per 100 lineal feet.										
Inches.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
2	·9646	1·097	1·239	1·389	..	..	..	..	..	..	..
3	·1269	·1444	·1630	·1827	..	..	..	..	..	..	..
4	·0302	·0343	·0387	·0434	·0483	·0536	·0590	·0648	·0708	·0772	·0837
5	·0097	·0110	·0123	·0129	·0158	·0172	·0194	·0208	·0232	·0244	·0274
6	·0038	·0044	·0049	·0055	·0063	·0070	·0079	·0080	·0093	·0096	·0110
7	·0018	·0020	·0023	·0026	·0029	·0032	·0035	·0040	·0043	·0044	·0051
8	·0009	·0010	·0012	·0013	·0015	·0016	·0019	·0020	·0022	·0028	·0026
9	·0005	·0005	·0006	·0006	·0008	·0009	·0010	·0011	·0012	·0014	·0015
10	·0002	·0003	·0503	·0003	·0005	·0006	·0005	·0006	·0007	·0007	·0008
11	·0001	·0002	·0002	·0002	·0003	·0003	·0003	·0004	·0004	·0004	·0005

D. or Diam. of pipe in inches.	G. or Gallons per minute.										
	26	27	28	29	30	35	40	50	60	70	80
	H. or Head used in a pipe per 100 lineal feet.										
Inches.	feet.	feet.	feet.	feet.	feet.	feet.	feet	feet.	feet.	feet.	feet.
4	·0904	·0976	·1072	·1126	·1205	·1640	..	..	..	..	..
5	·0292	·0300	·0336	·0369	·0395	·0537	..	..	..	..	..
6	·0106	·0128	·0132	·0148	·0158	·0215	·0288	·0441	·0635	·0864	·1128
7	·0056	·0059	·0064	·0068	·0073	·0099	·0124	·0204	·0294	·0400	·0524
8	·0028	·0036	·0032	·0035	·0037	·0050	·0064	·0103	·0150	·0205	·0276
9	·0014	·0016	·0018	·0020	·0021	·0029	·0035	·0058	·0084	·0114	·0148
10	·0008	·0008	·0011	·0011	·0012	·0016	·0021	·0034	·0049	·0067	·0088
11	·0005	·0006	·0006	·0006	·0007	·0010	·0014	·0021	·0031	·0042	·0056
12	·0003	·0004	·0004	·0005	·0005	·0007	·0008	·0013	·0019	·0027	·0032
13	·0002	·0002	·0002	·0003	·0003	0004	·0006	·0009	·0013	·0018	·0024
14	·0001	·0002	·0002	·0002	·0002	·0003	·0004	·0006	·0009	·0012	·0016
15	..	..	..	..	·0001	·0002	·0003	·0005	·0006	·0009	·0012
16	..	..	..	..	..	·0001	·0002	·0003	·0005	·0006	·0008
17	..	..	..	..	..	..	·0001	·0002	·0004	·0004	·0005
18	..	..	..	..	..	..	..	·0002	·0003	·0003	·0004
19	..	..	..	..	..	..	..	·0001	·0002	·0002	·0003
20	..	..	..	..	..	..	..	..	·0001	·0002	·0003
21	..	..	..	..	..	..	..	..	..	·0001	·0002

Water Works Table—concld.

D. or Diam. of pipe in inches.	G. or Gallons per minute.							
	90	100	200	300	400	500	600	700
	H. or Head used in a pipe for 100 lineal feet.							
Inches.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
6	·1429	·1764	·7056	1·587	2·829	4·41	6·350	8·644
7	·0661	·0816	·3264	·7344	1·305	2·04	2·938	4·000
8	·0339	·0418	·1272	·3762	·6698	1·04	1·505	2·051
9	·0188	·0232	·0928	·2088	·3712	·58	·8352	1·138
10	·0110	·0137	·0548	·1253	·2195	·3425	·4932	·6720
11	·0069	·0085	·0340	·0765	·1360	·2125	·3060	·4165
12	·0043	·0053	·0212	·0477	·0882	·1325	·1006	·2700
13	·0030	·0037	·0148	·0333	·0592	·0925	·1332	·1813
14	·0020	·0025	·0100	·0225	·0408	·0625	·0900	·1249
15	·0014	·0018	·0072	·0162	·0289	·0150	·0648	·0882
16	·0010	·0013	·0052	·0119	·0209	·0325	·0468	·0641
17	·0007	·0009	·0036	·0081	·0164	·0225	·0324	·0441
18	·0005	·0007	·0028	·0063	·0116	·0175	·0252	·0357
19	·0004	·0005	·0020	·0045	·0080	·0125	·0180	·0245
20	·0003	·0004	·0016	·0036	·0068	·0100	·0146	·0210
21	·0002	·0003	·0012	·0027	·0054	·0075	·0108	·0164

Discharge of Cast Iron Pipe by Kutter's Formula with N. =013 Discharge in gallons per minute.

Dia. of pipe	1/150	1/175	1/200	1/225	1/250	1/275	1/300	1/325	1/350	1/375	1/400	1/450
3	21	20	19	..	..	..	..	..	..	..	..	5
4	48	45	42	39	37	36	34	32	31	29	..	5
5	91	84	78	74	70	67	64	61	59	57	55	52
6	151	141	131	124	117	112	107	103	99	95	92	87
7	233	215	202	190	180	172	164	158	152	146	142	137
8	338	314	293	276	262	249	239	229	221	213	206	194
9	..	..	406	383	363	346	331	318	306	296	286	270
10	629	583	545	513	486	..	443	426	410	396	383	361
12	..	968	902	850	806	768	735	706	680	636	625	598
14	..	..	1378	1299	1232	1174	1125	1080	1040	1003	972	916
15	..	..	..	..	1490	1420	1359	1305	1256	1214	1174	1106
16	..	..	1990	1875	1779	1695	1623	1559	1501	1449	1371	1321
18	..	..	..	..	2455	2341	2241	2152	2071	2001	1935	1827
20	..	..	..	..	3275	3123	2988	2872	2766	2669	2584	2435
21	..	..	..	..	3743	..	3415	..	3158	..	2956	2783
22	..	..	..	..	4248	..	3877	..	3426	..	3352	..
24	..	..	..	..	5384	..	4916	4723	4545	..	4250	..
26	..	..	..	..	..	..	..	..	..	..	5283	4977
27	..	..	..	..	..	..	..	..	..	..	5852	5514
30	..	..	..	..	..	..	..	..	..	..	..	..

Discharge of Cast Iron Pipe by Kutter's Formula with N. =013 *Discharge in gallons per minute*—concluded.

Dia. of pipe	1/475	1/500	1/525	1/550	1/575	1/600	1/625	1/650	1/675	1/700	1/725	1/750
3	..	..	..	..	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	..	..	..	..
5	51	49	..	..	..	..	..	..	..	..	..	..
6	84	82	80	78	77	75	73	72	..	..	..	..
7	130	127	123	120	118	115	113	110	108	106	104	103
8	189	184	179	175	171	168	164	161	158	155	152	149
9	262	255	249	244	238	233	226	223	219	215	211	207
10	351	342	334	326	319	312	305	299	290	288	283	278
12	582	567	553	541	528	517	506	496	486	478	469	461
14	898	869	846	826	803	791	775	759	740	731	717	705
15	1076	1049	1023	1000	977	956	937	918	900	884	867	850
16	1284	1236	1201	1193	1166	1141	1118	1095	1075	1054	1036	1028
18	1774	1729	1687	1648	..	1576	1544	1513	1485	1457	1431	1406
20	2368	2308	..	..	..	..	..	2020	..	1945	..	..
21	2706	2636	2571	2513	2457	2403	..	2308	..	2222	..	..
22	..	..	..	..	..	2729	2672	2619	2569	2523	2477	2380
24	..	..	..	..	..	..	..	3320	..	3199	..	3087
26	..	4715	..	4495	..	..	..	4129	..	3976	..	..
27	..	5228	..	4980	..	4765	..	4574	..	4408	..	..
30	..	..	..	..	..	.	..	..	..	..	..	..

Resistance in Fittings.

Equivalent length of straight pipe of same diameter which would cause the same friction as the resistance in fittings.

Foot valve and strainer	.. .. ..	15 yards.
Sluice Valve full open	.. .. ..	½ yard.
Back pressure valve with hinged flap	.. ..	3½ yards.
Back pressure valve of the Globe Type	.. ..	45 ,,
Bends (radius 3 to 5 diameters	.. .. ..	1 yard.
Round Elbows	.. ..	3 yards.
Sharp Elbows and Tees	.. .. ..	6 ,,

To prevent excessive resistance in foot valve and strainer, the qualities below should not be exceeded for the various sizes of valves.

Size of valve in inches ..	2	2½	3	4	5
Gallons per minute ..	30	60	90	200	350
Size of valve in inches ..	6	7	8	9	10
Gallons per minute ..	500	800	1100	1500	2000

Water discharged from pipes at different velocities.

Imperial gallons per minute.

Diameter of pipe in inches.	*Velocity of water through pipe in feet per second.*						
	1	2	3	4	5	6	7
1	2·0	4·08	6·12	8·16	10·2	12·2	14·3
2	8·16	16·3	24·5	32·6	40·8	48·9	57·1
3	18·3	36·6	55·0	73·4	91·6	110	128
4	32·6	65·2	97·9	131·0	163	196	228
5	51·0	162	153	204	256	306	357
6	73·5	147	220	294	367	441	515
7	100·0	200	300	400	500	600	700
8	130·0	261	392	522	653	784	915
9	165	330	496	661	826	992	1158
10	204	408	612	816	1020	1224	1426
12	294	588	882	1175	1470	1764	2058

Distribution Mains and Service Pipes.

All pipes should be designed to deliver the supply in 8 hours. The velocity in the main should not exceed the following :—4″—3 feet per second, 6″—4 feet per second, 10″—5 feet per second, 16″—6 feet per second.

The velocity in the service pipes should not exceed 7 feet per second. The delivery from the tap should not be less than 5 gallons per minute. No service pipe should be less than $\frac{3}{4}$″ diameter but with high pressure $\frac{1}{2}$″ diameter may be used. A residual head not less than 5 feet should be allowed at tap.

For fire hydrants a flow of not less than 120 gallons a minute is necessary.

For very important buildings two hydrants should be provided and the main calculated for a flow of 240 gallons per minute.

The theoretical H. P. is the power required to raise a weight of 33,000 lbs. to a height of one foot in one minute. In pumping, this would be equivalent to raising 1,000 gallons of water to a height of 20 feet in one hour.

The following table show Theoretical Horse Power required to raise 1,000 gallons or 160·6 cubic feet of water per hour to various heights :—

Height in feet.	Horse power.	Height in feet.	Horse power.	Height in feet.	Horse power.	Height in feet.	Horse power.	Height in feet.	Horse power.	Height in feet.	Horse power.
1	·005	21	·106	41	·207	61	·308	81	·409	110	·556
2	·010	22	·111	42	·212	62	·313	82	·414	120	·606
3	·015	23	·116	43	·217	63	·318	83	·419	130	·657
4	·020	24	·121	44	·222	64	·323	84	·424	140	·707
5	·025	25	·126	45	·227	65	·328	85	·429	150	·758
6	·030	26	·131	46	·232	66	·333	86	·434	160	·808
7	·035	27	·136	47	·237	67	·338	87	·439	170	·859
8	·040	28	·141	48	·242	68	·343	88	·444	180	·910
9	·045	29	·146	49	·247	69	·348	89	·449	190	·960
10	·051	30	·152	50	·253	70	·354	90	·455	200	1·010
11	·056	31	·157	51	·258	71	·359	91	·460	210	1·061
12	·061	32	·162	52	·263	72	·364	92	·464	220	1·111
13	·066	33	·167	53	·268	73	·369	93	·470	230	1·162
14	·071	34	·172	54	·273	74	·374	94	·475	240	1·212
15	·076	35	·177	55	·278	75	·379	95	·480	250	1·263
16	·081	36	·182	56	·283	76	·384	96	·485	260	1·313
17	·086	37	·187	57	·288	77	·389	97	·490	270	1·364
18	·091	38	·192	58	·293	78	·394	98	·495	280	1·414
19	·096	39	·197	59	·298	79	·399	99	·500	290	1·465
20	·101	40	·202	60	·303	80	·404	100	·505	300	1·515

The above is one theoretical horse-power and in practice it is necessary to make an allowance, usually of about one-half for pump efficiency and frictional losses.

The diameter of the pipes through which water is pumped is a matter of great importance, especially where the distance is great. If pipes of too small diameter are used the power required may be very considerably increased.

When making enquiries with regard to Pumping Plants the following information should be given:—

1. Number of gallons per hour required.
2. Verticle height of suction from water to pump.
3. Horizontal distance from water to pump.
4. Verticle height of delivery piping.
5. Total length of delivery piping.

Cistern and Tanks.

Square tanks.—Thickness of plates for cast iron:—no plate less than ½ inch thick and when exceeding 6 feet depth, none less than ⅝ inch thick.

Formula for finding the thickness of plates.

$$\text{Square tank } t = \frac{d\sqrt{D}}{192}$$

Where t = thickness of plate in inches.
d = depth of plate in inches.
D = depth of lower edge from surface of water in feet.
Bolt diameter is t but not less than ¾ inch.

Approximate Weight of Iron Tanks; Plates ¼ inch thick.

Capacity.	Weight.			Capacity.	Weight.		
Gallons.	Cwt.	qrs.	lbs.	Gallons.	Cwt.	qrs.	lbs.
100	3	3	4	450	12	0	0
150	5	0	0	500	13	0	0
200	7	0	0	1000	26	0	0
250	8	0	0	1500	36	0	0
300	9	0	0	2000	47	0	0
350	10	0	0	3000	72	0	0
400	11	0	0	4000	86	0	0

Dimensions and Weight of Iron Water Tanks.

No.	Gallons.	Length.		Breadth.		Depth.		Weight.		
		Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	lbs.
1	600	4	0	4	0	6	0	10	1	14
2	500	4	0	4	0	5	0	8	2	16
3	400	4	0	4	0	4	0	6	3	25
4	200	4	0	2	0	4	0	4	2	25
5	200	4	0	4	0	2	0	4	2	25
6	193	4	0	4	0	2	0	5	1	20
7	200	3	3	3	3	3	3	4	2	25
8	100	3	3	1	8	3	3	2	3	20
9	100	3	3	3	3	1	9	2	3	20
10	376	4	0	4	0	4	0	6	2	25
11	264	4	0	3	6	4	0	5	2	2
12	110	3	3	2	6	2	10	2	0	6

Rule for finding the time of filling and emptying any tank.

Let T = time of filling the tank (when inlet and outlet are both open),
t = time of emptying the tank,
G = quantity of incoming water in gallons per minute,
g = quantity going out of tank in gallons per minute,
C = volume of tank in gallons.

Then $T=\frac{C}{G-g.}$ and $t=\frac{C}{g.-G.}$

Rule for finding time of emptying a tank with verticle sides and a hole at the bottom:—

Let A = Area of water surface in square inches.
a = Area of the hole in square inches.
D = depth of tank in feet.
T = time of emptying the tank in minutes.

Then $T=\frac{A\sqrt{D}}{222a.}$

Example.—Find the time of empyting a tank $5'\times5'\times4'$ with a $\frac{20''}{37}$ square hole at the bottom.

$A=5\times5\times144=3600$ square inches,

$\frac{3600\sqrt{4}}{222\times\frac{20}{37}}=60$ minutes, *i.e.*, one hour.

Weight of Air and Gases.

Air	13·14 c. ft.	per lb.	or	..	·0761 lb.	per c. ft	
Nitrogen	13·50	,,	,,	,,	..	·0741	,, ,,
Oxygen	11·58	,,	,,	,,	..	·0842	,, ,,
Hydrogen	189·70	,,	,,	,,	..	·0053	,, ,,
Carbon-monoxide	13·58	,,	,,	,,	..	·0738	,, ,,
Carbon dioxide	8·60	,,	,,	,,	..	·1163	,, ,,
Marsh gas	23·32	,,	,,	,,	..	·0429	,, ,,
Olefianult gas	13·46	,,	,,	,,	..	·0743	.. ..

The specific gravity of steam at atmospheric pressure is ·493 times that of air at 62° F. and ·0006 times that of water at same temperature.

26·4 c. ft. of steam at atmospheric pressure weigh one lb.

Hydraulic Ram.

The hydraulic ram affords a simple means of raising water when suitable conditions exist: by it water falling through any height from 4 feet to 40 feet may be made to raise a portion of itself to any greater height up to 10 times the height of fall. Efficiency 60 to 65 per cent.

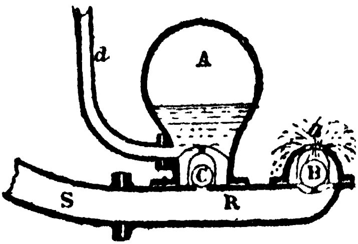
If G = gallons expanded per minute,

g = gallons to be raised per minute,

n = efficiency,

H = available fall,

h = height to which water is to be raised.



Then $G = \frac{g \times h}{H \times n}$

Where $n = 1{\cdot}12 - {\cdot}2\sqrt{\frac{h}{H}}$.—(*Molesworth*).

Table of Results of Operations of Hydraulic Rams.

Number of Strokes.	Height of Fall.	Height of Elevation.	Water Expanded.	Water Raised.	Useful Effect.
Min.	Feet.	Feet.	Cubic feet.	Cubic feet.	
66	10·06	26·3	1·71	·543	·9
50	9·93	38·6	1·93	·421	·85
36	6·05	38·6	1·43	·169	·75
31	5·06	38·6	1·29	·113	·67
15	3·22	38·6	1·98	·058	·35
10	1·97	38·6	1·58	·014	·18
..	22·8	196·8	·38	·029	·67

(*Kemp* 1919).

Thickness of Pipes for Hydraulic Accumulator Mains.

For 700 lbs per square inch:—

Armstrong .... $t = \frac{d}{2} + \cdot 25$

Brown .... t=

Thickness of pipes for water Co's mains :—

H = head of water in feet,
d = inside diameter of pipe in inches,
t = thickness of metal in inches,
x = ·37 for pipes less than 12 inches diameter,
= ·50 ,, from 12 to 30 ,, ,,
= ·60 ,, 30 to 50 ,, ,,
p = working pressure in lbs. per square inch,
r = inside radius of pipe in inches,
c = working strength of metal in lbs. per square inch,
= 3360 for cast iron and 500 for lead.

For 200 feet head :—

Hawksley .... $t = \cdot 18\sqrt{d}$

Unwin .... $t = \cdot 11\sqrt{d} + \cdot 1$

Box .... $t = \left(\frac{\sqrt{d}}{10} + \cdot 15\right) + \left(\frac{dH}{25000}\right)$

or say $= \frac{\sqrt{d}}{10} + \cdot 15 + \frac{d}{125}$

Molesworth.................... $t = \cdot 000054\ Hd + x$

or say $= 0108d + \frac{\sqrt{d}}{10}$

Rankine .... $t = \frac{Hd}{12000}$ or $\frac{\sqrt{d}}{48}$ which ever is greater, with a minimum of $\frac{3}{8}$ inches.

General Rules for thickness of Cast Iron Pipes :—

Unwin......................t $= \cdot 5d\left(\sqrt{\frac{2775+p}{2775-p}} - 1\right)$

Barlow ....t $= \frac{\cdot 5d}{\frac{16000}{p} - 1} \times 5$

Adams ....$t = \frac{dp}{6000} + \frac{\sqrt{p}}{100} + \frac{\sqrt{d}}{10}$ (+·125 per stem).

British Standard C. I. Pipes for Water and Sewage.

Diameter.	Test pressure 400 ft. head. Thickness.	External diameter.	Weight per 100 ft.	Test pressure 600 ft. head. Thickness.	External diameter.	Weight per 100 ft.	Test pressure 800 ft. head. Thickness.	External diameter.	Weight per 100 ft.	Depth of head for S. S. joints.	Weight of lead per S. S. joints.	Weight of yarn per S. S. joints.
ins.	ins.	ins.	cwt.	ins.	ins.	cwt.	ins.	ins.	cwt.	ins.	lbs.	lbs.
3	·38	3·76	12·8	·38	3·76	12·8	·40	3·76	13·3	1½	2·22	·24
4	·39	4·80	16·6	·40	4·80	16·7	·46	4·80	18 8	1½	2·77	·30
5	·41	5·90	21·7	·45	5·90	23·7	·52	5·90	26·8	1¾	5·73	·64
6	·43	6·98	27·2	·49	6·98	30·8	·57	6·98	34·8	1¾	6·64	·75
7	·45	8 06	33·3	·53	8·06	37·9	·61	8·06	42·8	1¾	7·66	·86
8	·45	9·14	40·0	·57	9·14	46·6	·65	9·14	52·4	2	9·71	1·10
9	·47	10·20	46·6	·60	10·20	55·5	·69	10·20	62·2	2	10·87	1·24
10	·52	11 26	54·1	·63	11·26	64·91	·73	11·26	72·4	2	12·03	1·37
12	·57	13·14	69·0	·69	13·14	85·5	80	13·60	97·1	2	14·1	1·67

Measurement of Water.

This is done by positive and inferential meters. Positive meters measure the actual quantity passing through them by filling and emptying chambers of known capacity by means of a piston actuated by the flow of water. The strokes of the pistons are recorded by means of a registering mechanism on an index and dial attached to the meter.

The following patterns are in use:—

(1) Kennedy, (2) Beck, (3) Worthington, (4) Sewel, (5) Kent's Standard and Uniform.

Inferential meters consist chiefly of a turbine worked by the flow of water and serving as a measure of the velocity of water passing through. An index on a dial is moved by gearing to indicate the volume of water passing through the meter.

The following patterns are in use:—

(1) Worthington Disc, (2) Siemens, (3) Taylor.

The loss of head in meter varies with the type and as the square of the discharge. Allowance for this should be made in the calculation for hydraulic gradient.

For small supplies the main meter on the rising main should be of the positive type. A meter of the inferential type will do on distributing mains.

For large supplies Venturi meter should be used.

Hot Water Supply.

Amount of Hot Water Storage Required:—

Bath	20 to 30 gallons.
Lavatory Basin	2 to 3 gallons.
Scullery Sink	5 to 10 gallons.

Heating Power of Boilers.—Minimum 50 degrees per hour.

Material for Boilers.—Boilers are made of cast iron, wrought iron, steel and copper.

A copper boiler transmits 5 per cent. more heat than others.

Boiler Efficiency.—Is based on fuel consumed, it means the percentage of fuel energy absorbed by the water out of that emitted by the fuel consumed on the boiler grate.

Example.—Find the approximate amount of fuel required to heat 100 gallons of water per hour from 60° to 150° F., the boiler efficiency being 50 per cent.

100 gallons = 1000 lbs.

1000 lbs. of water raised 90 degrees, requires

$1000 \times 90 = 90{,}000$ B. T. U.

Assuming coke is to be used in boilers, with a calorific value of 12,500 B. T. U. per pound, then the amount of fuel required is :—

90,000 for raising water 90 degrees.
1,500 Say loss by radiation.
Total 1,01,500 B. T. U.

$$\text{Coke required} = \frac{1{,}01{,}500}{12{,}500} \times 50\% \text{ efficiency}$$
$$= \frac{1{,}01{,}500}{12{,}500} \times \frac{100}{50}$$
$$= 16 \text{ lbs. per hour approx.}$$

The size of the primary circuit should be proportionate to the heating power of the boiler.

The following table shall serve as a guide—

Approximate heating power of boiler in B. T. U. per hour.	Up to 25,000	25,000 to 50,000.	50,000 to 80,000.	over 80,000.
Size of primary flow and return pipe.	1″	1¼″	1½″	2′

A covering of hair felt ¾″ to 1″ in thickness will reduce heat losses by about 80 per cent.

Table of pipe surfaces in sq. feet of radiation for 1 *lineal foot—*

Diameter of pipe in inches ..	½	¾	1	1¼	1½	2	2½	3
Surface per foot run..	·221	·275	·346	·434	·494	·622	·753	·916

Warming by hot water.

$$L = \frac{\cdot 018C\,(P-t)\,(T-t)}{D\,(P-T)}$$

Where L = length of pipe in ft.
C = c. ft. of air to be warmed per minute,
P = temperature of pipes in Fahr.,
t = temperature of external air in Fahr.,
T = temperature required in building in Fahr.,
D = diameter of pipes in inches.

For every 100 sq. ft. of pipe surface, allow 30 to 50 sq. inches of fire grate area. Is very expensive in first cost, but by far the cheapest in fuel of any other method.

SEWAGE AND DRAINAGE.

Sewers.

(1) Combined system of sewerage is one in which both storm water and sewage is carried in the same channels.

(2) A separate system of sewage is one in which only sewage is carried.

The capacity of sewers are fixed to carry off the greatest volumes of the respective liquids that it is proposed to carry, taking into account the maximum rates of discharge from the various sources and the times when the maximum rates are likely to occur. In general however the volume of sewage is equal to the volume of water-supply.

Discharging Capacity of Sewers.

$$V=124\ R^{\frac{2}{3}}\ S^{\frac{1}{2}}.$$

$$Q=AV,$$

where, Q=discharge in cubic feet per second.

V=Velocity in feet per second.

R=Hydraulic mean depth in feet.

S=Sine of angle of inclination.

A=Area of the cross section of sewer in square feet.

For Circular Sewers:—

$$V=\frac{9{\cdot}4\sqrt[3]{D^2}}{\sqrt{i}}$$ (when sewer is running full or half full).

Where V=Velocity of flow in feet.

D=Diameter of sewer in inches.

i=Length ÷ Fall.

When depth=·9 D then V=10 per cent. more, and
when depth=·25D then V=25 per cent. less.

For Egg-Shaped Sewers Running ⅔rd full (Kutter's formula) —

d=diameter of larger circle in feet.

V=velocity in feet per second.

Q=discharge in c.ft. per second.

n=co-efficient =·013.

Table of Velocity and Discharge in Egg-shaped Sewers.

Slope 1 in.		d=2 ft.	d=2½ ft.	d=3 ft.	d=3½ ft.	d=4 ft.	d=5 ft.
500	—V	3·80	4·44	5·04	5·59	6·12	7·00
	—Q	11·47	20·96	34·21	51·69	73·64	133·68
600	—V	3·47	4·05	4·50	5·10	5·58	6·47
	—Q	10·46	19·11	31·20	47·16	67·37	121·98
700	—V	3·20	3·75	4·25	4·72	5·16	5·98
	—Q	9·67	17·68	28·86	43·63	62·33	112·88
800	—V	2·99	3·50	3·97	4·41	4·83	5·59
	—Q	9·04	16·52	26·98	40·78	58·26	105·53
900	—V	2·82	3·30	3·74	4·16	4·55	5·27
	—Q	8·51	15·56	25·41	38·42	54·90	99·46
1000	—V	2·67	3·13	3·55	3·94	4·31	5·00
	—Q	8·07	14·75	24·09	36·42	52·05	94·30
1200	—V	2·54	2·98	3·38	3·75	4·10	4·76
	—Q	7·67	14·03	22·93	34·68	49·56	89·86
1400	—V	2·25	2·63	2·99	3·32	3·63	4·22
	—Q	6·79	12·42	20·29	30·70	43·88	79·56
1600	—V	2·10	2·46	2·79	3·10	3·40	3·94
	—Q	6·33	11·59	18·95	28·67	41·00	74·35
1800	—V	1·97	2·31	2·63	2·92	3·20	3·71
	—Q	5·96	10·91	17·84	27·00	38·65	70·04
2000	—V	1·87	2·19	2·49	2·77	3·03	3·52
	—Q	5·64	10·33	16·90	25·57	36·58	66·39
2500	—V	1·66	1·95	2·22	2·47	2·70	3·14
	—Q	5·02	9·20	15·05	22·80	32·62	59·24
3000	—V	1·51	1·77	2·02	2·24	2·46	2·86
	—Q	4·56	8·36	13·69	20·74	29·69	53·96
4000	—V	1·29	1·52	1·73	1·93	2·12	2·47
	—Q	3·91	7·18	11·76	17·84	25·57	46·54
5000	—V	1·15	1·35	1·54	1·72	1·88	2·20
	—Q	3·46	6·36	10·45	15·86	22·75	41·45

(Molesworth.)

When running full the velocity is about ·94 V and the discharge about 1·43Q. For other values of n multiply the tabular numbers by K.

If n=	·010	·011	·012	015	·017
K=	1·38	1·25	1·11	·84	·71

Table of Slope and Discharge in Egg-shaped Sewers when running full (old form) D=1½d.

Velocity in ft. per second.		d=2 ft.	d=2½ft.	d=3 ft.	d=3½ ft.	d=4 ft.	d=5 ft. 4″
2	S	1 in 1850	1 in 2500	1 in 3200	1 in 3900	1 in 4700	1 in 6890
	Q	9·188	14·356	20·674	28·138	36·752	65·336
2½	S	1 in 1200	1 in 1600	1 in 2050	1 in 2500	1 in 3000	1 in 4400
	Q	11·485	17·945	25·842	35·172	45·940	81·670
3	S	1 in 825	1 in 1100	1 in 1400	1 in 1700	1 in 2075	1 in 3050
	Q	13·782	21·534	31·010	42·206	55·128	98·004
3½	S	1 in 600	1 in 815	1 in 1050	1 in 1280	1 in 1525	1 in 2250
	Q	16·079	25·123	36·178	49·240	64·316	114·338
	S	1 in 460	1 in 625	1 in 800	1 in 975	1 in 1175	1 in 1700
	Q	18·376	28·712	41·346	56·274	73·504	130·672
4½	S	1 in 355	1 in 500	1 in 630	1 in 775	1 in 925	1 in 1350
	Q	20·673	32·301	46·514	63·308	82·692	147·006
5	S	1 in 300	1 in 400	1 in 500	1 in 625	1 in 750	1 in 1100
	Q	22·970	35·890	51·682	70·342	91·880	163·340

Table of Slope to give the following Velocities when running full or half full.

Velocity in ft. per second.	Diam. 8″	Diam. 9″	Diam. 10″	Diam. 12″	Diam. 15″	Diam. 18″	Diam. 21″	Diam. 24″	Diam. 27″	Diam. 30″
2	1in350	1in415	1in475	1in610	1/820	1/1050	1/1275	1/1525	1/1775	1/2050
2½	1in225	1in265	1in305	1in385	1/520	1/660	1/820	1/970	1/1138	1/1315
3	1in155	1in185	1in210	1in270	1/365	1/460	1/570	1/680	1/790	1/910
3½	1in115	1in135	1in155	1/200	1/265	1/340	1/415	1/500	1/585	1/670
4	1in88	1in105	1in120	1/150	1/205	1/260	1/320	1/380	1/445	1/515
4½	1in70	1in82	1in94	1/120	1/160	1/205	1/250	1/300	1/352	1/405
5	1in56	1in66	1in76	1/97	1/130	1/165	1/205	1/245	1/285	1/330
5½	1in47	1in55	1in63	1/80	1/105	1/138	1/170	1/200	1/234	1/270
6	1in39	1in39	1in53	1/67	1/91	1/115	1/140	1/170	1/197	1/230

Table showing the proper Inclination of Sewers one foot in diameter when running full and working under various heads.

The proper Inclination of any other sized Sewer may be found by multiplying the Inclination given in this Table, by the diameter of Sewer in feet or decimal parts of feet.

h=	v=2′.	v=2·5′.	v=3′.	v=3·5′	v=4′.	v=4.5′	v=5′.	v=5.5′	v=6′.	v=7′.	v=8′.	v=9′.	v=10′.
feet.													
·5	1: 497·5	1: 290·5	1: 171·2	1: 95·6	1: 44·3	1: 17·5	..	..	..	..	..	..	..
1·0	554·7	350·4	233·4	159·6	110·0	74·7	1: 48·6	1: 28·8	1: 13·3	..	..	..	..
1·5	573·8	370·4	254·1	180·9	131·8	97·1	71·4	52·0	36·8	1: 15·0	..	..	..
2·0	583·3	380·4	264·5	191·6	142·8	108·3	82·8	63·7	48·6	27·0	1: 12·4	1: 2·1	..
2·5	589·1	386·4	270·7	198·0	149·4	115·0	89·7	70·6	55·7	34·2	19·8	9·6	1: 2·1
3·0	592·9	390·4	274·8	202·3	153·8	119·5	94·2	75·3	60·4	39·0	24·7	14·6	7·2
3·5	595·6	393·2	277·8	205·3	156·9	122·7	97·5	78·6	63·8	42·5	28·2	18·2	10·8
4·0	597·7	395·4	280·0	207·6	159·3	125·1	99·9	81·1	66·3	45·1	30·9	20·9	13·6
4·5	599·3	397·0	281·7	209·4	161·1	127·0	101·8	83·0	68·3	47·1	32·9	23·0	15·7
5·0	600·5	398·4	283·1	210·8	162·6	128·5	103·4	84·6	69·8	48·7	34·5	24·7	17·4
5·5	601·5	399·5	284·3	212·0	163·8	129·7	104·6	85·9	71·1	50·0	35·9	26·1	18·8
6·0	602·4	400·4	285·2	213·0	164·8	130·7	105·7	86·9	72·2	51·1	37·0	27·2	19·9
7·0	603·8	401·8	286·7	214·5	166·3	132·3	107·3	88·6	73·8	52·8	38·8	29·0	21·3
8·0	604·8	402·9	287·8	215·6	167·5	133·5	108·5	89·8	75·1	54·1	40·1	30·3	23·2
9·0	605·6	403·7	288·7	216·5	168·4	134·5	109·5	90·8	76·1	55·1	41·1	31·4	24·2
10·0	606·3	404·4	289·3	217·2	169·1	135·2	110·2	91·6	76·9	55·9	41·9	32·2	25·0
20·0	609·1	407·3	292·5	220·4	172·0	138·6	113·6	95·0	80·4	59·5	45·6	36·0	28·9
50·0	610·8	409·2	294·4	222·4	174·4	140·6	115·7	97·1	82·5	61·7	47·8	38·2	31·1
Infinite	612·0	410·4	295·6	223·6	175·7	141·9	117·0	98·5	84·0	83·2	49·3	39·7	32·7

NOTE.—h in the Table represents the total fall in a given length of sewer. The length of sewer taken into consideration is found by multiplying h by the rate of inclination of the sewer. *Example*:—A sewer 1 foot in diameter with a velocity of 3 feet per second, has a total fall from head to outlet of 6 feet, then $6 \times 285·2 = 1,711·2$ feet is the length of sewer for this fall. If the sewer is 6 feet diameter and the velocity required is 3 feet, the total fall being 6 feet, the proper inclination would be $6 \times 285·2 = 1$ in 1,711, and the length of sewer taken into the calculation is $6 \times 1,711 = 10,266$.

The slope for sewers should as far as possible be enough to induce self-cleaning velocity. Brick sewers on slopes that produce more than 7 to 10 ft. velocity wear rapidly especially on the bottom.

Brick sewers should in all cases be set in hydraulic mortar or in cement.

Brick sewers ought to be formed with bricks moulded to radii.

In no case should any sewer be formed with bricks set dry to be subsequently grouted.

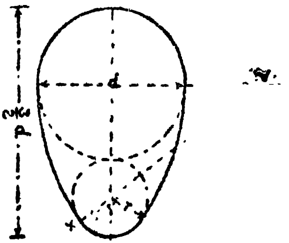
Shapes of Sewers :—

Round sewers are used up to 24″ diameter. The round sewers is the most economical of materials for a given carrying capacity.

Egg-shaped sewers are small at bottom and large at top. This form of sewer gives a fair hydraulic mean depth. It is advantageous on combined system. Besides, this form is more easily entered by workmen than the round section. The following figures show two different types of this form of sewers.

EGG-SHAPED SEWER (OLD FORM)

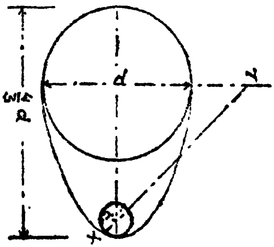
A



$r = \frac{d}{4}$, $XY = 1\frac{1}{2}d$

EGG SHAPED SEWER (NEW FORM)

B



$XY = 1\frac{1}{3}d$

	Items.		Full.	⅔ Full.	⅓ Full.
A	Area of Section	..	1·1475 d^3	·7548 d^2	·2840 d^2
	Wetted Perimeter	..	3·9649 d	2·3981 d	1·3746 d
	Hydraulic mean depth	..	·2897 d	·3157 d	·2066 d
B	Area of Section	..	1·1150 d^2	·7223 d^2	·2543 d^2
	Wetted Perimeter	..	3·9205 d	2·3497 d	1·3246 d
	Hydraulic mean depth	..	·2844 d	·3074 d	·1920 d

Sewage Disposal Works.—

The processes involved in sewage disposal works may be classified as follows:—

(1) Preparatory processes including screens, roughing filters, detritus tanks, settling tanks, septic tanks and chemical precipitation tanks.

(2) Purification processes including sub-surface irrigation, broad irrigation, intermittent filtrations, contact beds and sprinkling filters.

(3) Finishing processes for clarification are sendimentation and coarse filtration, while those for bacterial improvement are land treatment, sand filtration, mechanical filtration and disinfection.

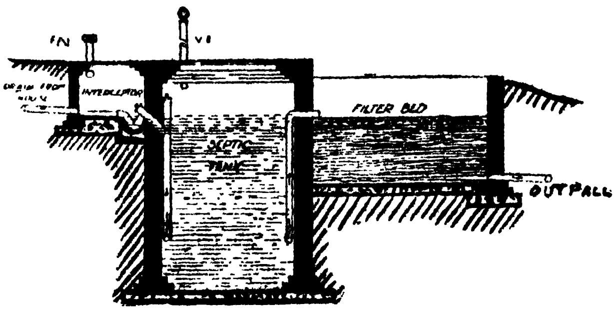
Septic Tanks.—The sewage from the house drains is taken in as direct line as possible into a water-tight chamber brick-built and lined with cement rendering, glazed bricks or other impervious material, covered at the top but provided with an air-tight main-hole cover for access. A ventilation pipe should be carried from the top of the chamber to some high point near (up a tree for example) and a fresh air-inlet with mica valve be provided.

Adjoining the septic tank, another chamber is built to be used as a filter and æration bed. This need only be cement lined. The top is left entirely open. A pipe is taken from about 6 inches above the bottom of the first chamber vertically up the side and overflowing over the filter bed about 6 inches below the top of the filter bed. The filter bed is filled to within 6 or 9 inches of the top with furnace clinker broken bricks or charcoal, 1 inch to $\frac{1}{8}$ inch, the smallest size being at the top. The effluent from the septic tank is thus delivered over the ashes into the filter or æration bed, and the liquid discharge percolates through the ash bed and is in turn discharged through an outlet at the bottom of the filter bed.

The Septic tank for a house of eight rooms may be 4 feet by 3 feet or 4 feet diameter on plan, and 8 feet deep; the æration bed being 4 feet 6 inches wide by 6 feet long, and 4 feet, 6 inches deep. Other sizes should be in proportion to the size of the buildings served.

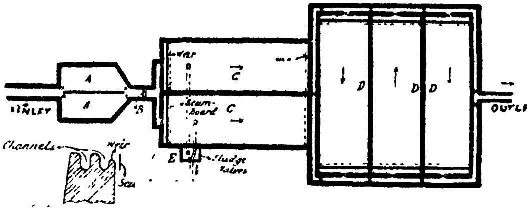
A galvanised iron wire grating should be laid over the filter bed to prevent the accumulation of leaves or other rubbish.

SEPTIC TANK.



Allow 250 gallons of sewage per square yard.

For sewage disposal works on larger scale a septic tank of the type described below may be used in which the sludge is allowed to remain and partially to decompose into liquids and gases.



The sludge water first enters one of the grit tanks A, A, which are small tanks, capacity ½ hour flow, depth about 3½ feet, where sand, clay, etc., settle. Grit tanks are provided in duplicate, one in use, one thrown out for cleaning ; cleaning can be done by hand, the sludge extracted being trenched. B is a screen to arrest floating matter : it is made of inclined ½" bars about ½" apart. C, C, are primary tanks and D, D, D, secondary tanks. Ordinarily the sewage is let into both the primary tanks and then led through the secondary tanks in series. Most of the sludge is settled in the primary tanks and sludge valves should be provided at the bottom near the entrance, the bottom of the tank being sloped to this point. The sludge pipes should lead to a valve chamber E, whence the pipes are led away to trenches. The sludge outlet level should be 3 feet below the water level to allow sufficient head to force the sludge through.

Tanks D, D, D, may be made flat bottomed : sludge will accumulate in them very slowly and clearing out can be done by hand. The sewage enters and leaves each of the tanks over a level crested weir beyond which is placed a sludge board, dipping about 9 inches into the water. The total capacity of the primary and secondary tanks should amount to about 12 hours flow : their length should be 3 times their breadth and their depth 6 feet : they should be covered with loose boards or some covering that permits of free ventilation but prevents mosquito breeding. Stormwater should be excluded, and it may be necessary to provide some form of storm overflow or method of diverting the drainage to a nullah. Grit tanks will probably require cleaning daily : for the Septic tanks the sludge should be measured periodically and the depth should not exceed 1 foot : the sludge valves of the primary tanks should be opened once a month until the water level in the tanks has dropped 1 foot. Scum should not be allowed to get more than 3" thick. Penstocks, *i.e.*, boards sliding in grooves, are provided where marked X and enable any tank to be cut out.

DISPOSAL BY IRRIGATION.

Broad irrigation consists in the application of sewage to land so that it may serve as food to crops, the liquid being spread over the surface by means of ditches and other channels as in the ordinary irrigation of land.

CONTACT BEDS.

Contact filters consist of water-tight compartments filled with porous material used for the purification of sewage in the following manner: the bed is slowly filled with sewage and allowed to remain full for a certain period, after which it is slowly emptied and allowed to remain empty for a longer period of rest. The applied sewage is usually first subjected to a preparatory treatment, either plain or septic sedimentation. The number of times a day that the bed is filled and emptied depends upon the volume and character of sewage, the nature of the material in the tank and other factors. In England it is common to employ three cycles a day, allowing one hour for filling, two hours for contact, one hour for emptying and four hours for rest. The principal factor involved in this method of purification is sedimentation, but chemical and biological processes are also at work. During the period of contact the suspended matter of the sewage tends to settle on and adhere to the exposed surfaces of the material filling the bed. Some of this washes out when the bed is emptied, but much of it remains behind. While the bed is standing full an aerobic conditions exist and septic action occurs. There is also an absorption of organic matter by the accumulated film. When the bed is being emptied air is drawn into it and in consequence of this there is a partial oxidation of the organic matter adhering to the material in the bed. While the bed is resting, aerobic conditions prevail. The result is a partial removal of suspended matter and a slight amount of oxidation of the organic matter, the degree of purification depending upon the character of the sewage and the opportunities permitted for sedimentation and oxidation.

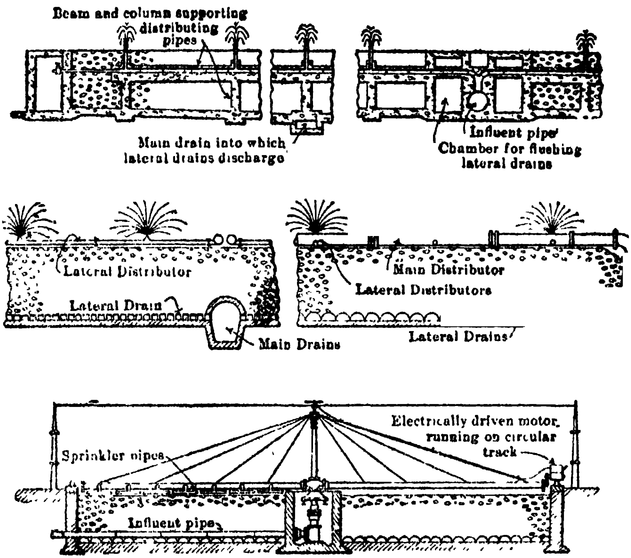
SPRINKLING FILTERS.

Sprinkling filters consist of beds, with or without side walls, filled with porous material and thoroughly under-drained with tiles or channels in the concrete floor, the whole so arranged as to provide thorough æration of both drains and filtering material. The sewage is applied at the surface by means of fixed or moveable sprinklers in such a manner that it becomes well ærated before it enters the bed. It percolates downward through the material and flows out of the under-drains.

The fundamental idea of sprinkling filters is the greatest possible exposure of the sewage to the air with the oxidation of organic matters and nitrification and the construction of the filter in such a way that no deposit of suspended matter in it is possible. If there is a deposit of suspended matter in the filter the filter will become clogged, the air supply shut off and the process interrupted. The design should therefore permit flushing and cleaning of the lower parts.

Three types of sprinkling filters commonly used are sketched below:

SPRINKLING FILTERS.



FINISHING PROCESSES.

The effluent from sprinkling filters is not clear but contains large quantities of suspended matter. This suspended matter is removed by sedimentation or by filtration through coarse material such as broken stone, coke, slag, etc. The sludge obtained in this way is more stable and less objectionable than that from plain settling tanks or septic tanks. Although the effluents from contact beds and sprinkling filters contain fewer bacteria than the applied sewage, they are not bacteriologically pure enough to materially improve the character of a stream from the stand-point of water-supply.

Drains.

Before any system of drains, can be designed it is absolutely necessary, that an accurate plan, showing all levels of the area drained, roads, streets, etc., should be prepared. All existing drainage channels should be carefully surveyed and levels taken.

All water sheds lying betwe[illegible]n drains should be marked in red.

Capacity of Drains.—For sullage water it may be assumed that the whole of the water-supply will find its way to the drains which must be large enough to carry away the whole quantity in 8 hours. For bazaars it is usual to make an allowance of 2 gallons per head per hour.

The capacity of storm water drains will depend on the nature of the soil, the slope, the maximum rate of rainfall and the proportion of the area occupied by buildings. Where the rainfall is heavy and frequently exceeds 1″ per hour, drains should usually be designed to carry away a run-off of ½″ an hour: in dry localities where heavy rainfalls are rare, a run-off of ¼″ an hour may be assumed for main drains and as low as $\frac{1}{10}$″ for side-drains. A run-off of ½″ is equivalent to a flow of ½ cusec from an acre or ·0116 cusecs per 1000 square feet.

Gradients for Drains :—

For 4″ pipes gradient .. ..1 in 40.
For 6″ pipes gradient .. ..1 in 70.
For 9″ pipes gradient .. ..1 in 100.

When it is not possible to keep to these gradients, it is advisable to lay the branch drains at any rate to those self-cleansing gradients, and to provide for periodically flushing the main drains.

Shapes of Drains.—For small flows semi-circular drains may be used but where the drain has to be calculated for large storm water flow the peg top section is suitable. A type of the peg top section is give below.

Dimensions of Peg Top Drain :—

	Full.	⅔ Full.	⅓ Full.
Area of Section ..	1·0385 d^2	·6458 d^2	·2422 d^2
Wetted Perimeter ..	3·8780 d	2·3072 d	1·2706 d
Hydraulic mean depth ..	·268 d	·280 d	·1905 d

Discharge formula :—

$$V=9{\cdot}42\sqrt{h\times f} \text{ or } 1{\cdot}3\sqrt{h\times F}.$$

$$R=\frac{V^2}{88{\cdot}7f} \quad \text{or} \quad \frac{V^2}{1{\cdot}69F}.$$

$$f=\frac{V^2}{88{\cdot}7\,R} \text{ and } F.=\frac{V^2}{1{\cdot}69\,R}.$$

$$Q=AV$$

Where :—

V=velocity in feet per second,

R=hydraulic mean depth $\frac{\text{A (area)}}{\text{wetted perimeter}}$,

f=fall in feet per hundred,

F=fall per mile,

A=Area of section in square feet,

Q=Discharge in cubic feet per second.

Table showing Area, Wetted Perimeter and Hydraulic mean depth for different Types of Drains.

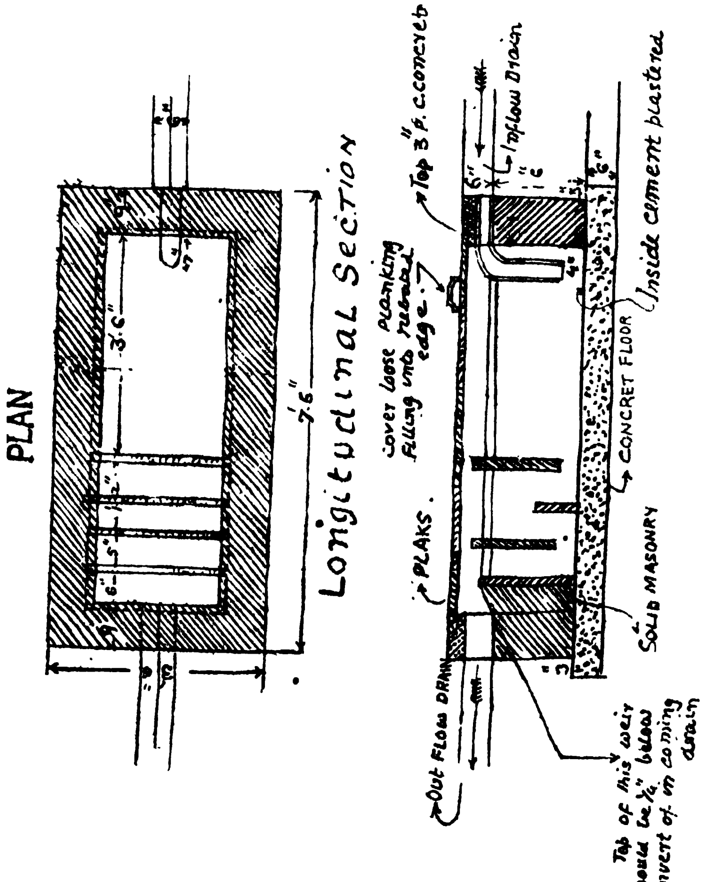
Type.	Section No.	Area.	Wetted perimeter	Hydraulic mean depth.	REMARKS.
I	(1)	·025	·48	·06	$\frac{2}{3}$rd full.
	,,	·07	·71	·09	$\frac{2}{3}$rd ,,
	,,	·119	·87	·136	full.
II	(2) (2)	·06	·62	·099	$\frac{1}{3}$rd full.
	,,	·12	·96	·125	$\frac{2}{3}$rd ,,
	,,	·25	1·27	·197	full.
III	(3) (3)	·09	·87	·103	$\frac{1}{3}$rd full.
	,,	·26	1·37	·189	$\frac{2}{3}$rd ,,
	,,	·476	1·80	·263	full.
IV	(4) (4)	·147	1·04	·141	$\frac{1}{3}$rd full.
	,,	·409	1·70	·240	$\frac{2}{3}$rd ,,
	,,	·75	2·35	·319	full.
V	(5) (5)	·206	1·21	1·70	$\frac{1}{3}$rd full.
	,,	·594	2·10	·283	$\frac{2}{3}$rd ,,
	,,	1·076	2·89	·370	full.
VI	(6) (6)	·278	1·41	·198	$\frac{1}{3}$rd full.
	,,	·804	2·46	·327	$\frac{2}{3}$rd ,,
	,,	1·45	3·42	·42	full.

Note.—For sketches of different types of drains see pages 776-782, Part II.

Flushing Drains.—For small side-drains a bahisti and a sweeper can clean up 3,000 running feet morning and evening. For larger drains special flushing arrangements are necessary : an efficient method is to place vertical boards in grooves at intervals of 150 to 200 feet and to let the water pond on when it will proceed with a rush on the boa d being removed. For main drains a flush of 250 gallons twice a day will be necessary.

Grease Traps.—All grease and solids must be removed in a trap; for this purpose a kerosine oil tin placed in the centre of the pit may be used, the tin being well perforated towards the bottom and filled with saw dust covered with grass.

GREASE TRAP.

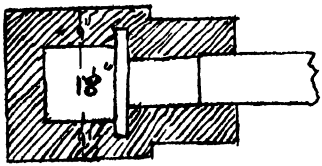


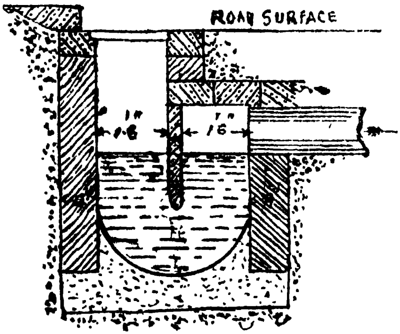
Gully Trap.

The depth of the seal of surface water gullies in India should never be less than 9″ on account of evaporation.

During the dry season fill in all water gullies with clear sand; this prevents foul air coming out in the street.

WATER GULLY





Disposal of City Refuse.

City refuse consists of various solid substances incapable of being carried by sewers. It is collected by hand in cans and removed by the municipality in carts.

Refuse Incenerations consist of burning the mixed refuse of a city including ashes, rubbish, manure, etc. Minimum temperature of combustion is 1250° F. and maximum seldom above 2000° F.

MECHANICAL ENGINEERING.

Steam Engines.

Properties of Steam :—

1 British Thermal Unit	= 778 ft. lbs.
2545 British „ units per hour	= 1 H. P.
One atmosphere	= 14·7 lbs. per sq. inch.
One pound pressure per sq. inch	= 2·035 inches of mercury.
Specific heat of saturated steam at constant pressure	= ·48
„ „ „ „ „ „ „ volume	= ·37

Absolute zero = 461·2 below zero Fah.

Velocity of steam should not exceed 90 ft. per second; in steam pipes 85 ft. per second.

If A = area of piston.
V = velocity of piston ft. per minute.

$$\text{Area of steam port} = \frac{AV}{90} = \cdot 011\ AV.$$

To calculate the amount of steam required to heat a given quantity of water

$$W = \frac{10 \times G \times (T-t)}{H-T+32.}$$

Where W = pounds of steam required
G = gallons of water
T and t = temperatures Fah. after and before heating
H = total heat per pound of steam

Advantage of expanding steam :—

When steam is cut off at ⅝ of the stroke, the power of an engine is only diminished by 7 per cent. while the consumption of coal is diminished by 33 per cent. When cut off at ½ stroke the power is reduced 16 per cent. and the consumption of steam 50 per cent.

Economy of Compound Engines :—

The economy of compound engines consists mainly in the higher pressure of steam employed permitting greater expansion and in the sub-division of the work over two or more cylinders, limiting the range of temperature in each and therefore the loss from condensation.

Number of Expansions :—

The steam is usually expanded in :—

Simple condensing engine	from	3 to 5 times.
Two cylinder compound	„	7 to 9 times.
Triple compound	„	12 to 15 times.
Quadruple compound	„	16 to 18 times.

The total expansion is found by dividing the capacity ($d^2\, l$) of the low pressure cylinder upto point of release by the capacity ($D^2\, l$) of high pressure cylinder upto point of cut-off. Intermediate cylinders do not affect the ratio.

Cylinder Ratios :—

Two cylinder compound :—Common rule.

Diam. low pressure cylinder = 2 inches less than twice the diam. of high pressure cylinder.

High Pressure Engines (Single Cylinders).

Non-condensing (short stroke).

Cylinder: Diam. × Stroke.		4½″ × 8″		5½″ × 8″		6½″ × 10″		7½″ × 10″		8″ × 12″		9″ × 12″	
Revolutions per Minute.		260	190	260	190	210	170	210	170	175	140	175	140
B. H. P. Pressure at Stop Valve.	60 lbs. ..	4¾	3½	7¼	5¼	10	8½	14	11	15½	12½	20	16
	80 ,, ..	6	4¼	9¼	6¾	13	10½	17½	14	20	15½	25	20
	100 ,, ..	7	5¼	10½	7¾	15	12	20	16	23	18	29	23

Non-condensing (slow speed).

Nominal. H. P.	CYLINDER.		Revolutions per minute.	INDICATED HORSE-POWER.	
	Dia.	Stroke.		Economical.	Maximum.
	ins.	ins.			
10	10	20	110	35	45
12	11	20	110	40	55
14	12	24	90	45	65
16	13	24	90	55	75
20	14	28	80	65	85
22	15	28	80	75	95
25	16	32	70	85	110
28	17	32	70	95	125
32	18	36	60	105	140
36	19	36	60	115	155

Boiler Pressure.—In calculating the powers given above, a boiler pressure of 80 lbs. has been assumed. These Engines may also be worked at 100 lbs. pressure.

Condensing Engines.—Engines fitted with condensers will develop economically one-fifth more power than is given in this table. In this case the engines should not be worked at more than [illegible] lbs. pressure.

Compound Long-stroke Engines.

CYLINDERS.			FLYWHEEL.			GROOVED FLY-WHEEL.		INDICATED HORSE-POWER.			
Diameter.		Stroke	Dia.	Face	Rev. per min.	Ropes.		At 120 lbs. pressure, non-condensing.		At 100 lbs. pressure, condensing.	
High Pressure.	Low Pressure.					No.	Dia.	Econ.	Maxm.	Econ.	Maxm.
ins.	ins.	ins.	ft. ins.	ins.			ins.				
8	13½	20	7 0	8	115	4	1¼	42	48	42	52
9½	16	24	8 2½	10	90	5	1¼	56	66	56	70
10½	18	28	9 0	12	80	5	1½	76	88	76	94
12	20½	32	10 0	14	70	7	1½	100	116	100	124
13½	22½	36	12 0	16	65	6	1¾	130	150	130	160

PROPERTIES OF SATURATED STEAM.

Absolute Pressure. Lbs. per sq. in.	Temperature. ° F.	Water Heat from 32° F.	Latent Heat of Vapourization.	Total Heat per Lb. B. Th. U.	Volume, Cub. Ft. per Lb.	Absolute Pressure. Lbs. per sq. in.
1	101·8	69·8	1035	1105	333	1
2	126·1	94·2	1022	1116	173	2
3	141·5	109·6	1012	1122	118·4	3
4	153·0	121·0	1006	1126	90·4	4
5	162·3	130·3	1000	1130	73·3	5
6	170·1	138·1	996	1134	61·9	6
7	176·8	144·9	991	1136	53·6	7
8	182·9	150·9	988	1139	47·3	8
9	188·3	156·4	985	1141	42·4	9
10	193·2	161·3	981	1143	38·4	10
11	197·7	165·9	979	1145	35·1	11
12	202·0	170·1	976	1146	32·4	12
13	205·9	174·1	974	1148	30·1	13
14	209·6	177·8	971	1149	28·0	14
14·72	212·0	180·2	970	1150	26·7	**14·72**
15	213·0	181·3	969	1150	26·3	15
16	216·3	184·6	967	1152	24·7	16
17	219·4	187·8	965	1153	23·4	17
18	222·4	190·8	963	1154	22·2	18
19	225·2	193·7	961	1155	21·1	19
20	228·0	196·4	959	1156	20·1	20
21	230·6	199·1	957	1157	19·19	21

Strength of boilers.—

Strength of plate	.. ..	100
Strength of single riveted joints	.. ..	56
Strength of double riveted joints	.. ..	70

The actual Horse Power of a boiler is estimated by the number of cubic feet of water evaporated into steam per hour. The simplest way of ascertaining the actual evaporation of any boiler is as follows:—

When the boiler is working satisfactorily, feed the boiler up to the top of the water gauge glass; then shut off the feed, weigh all the coal used after this time, and observe the time occupied in reducing the water from the top to the bottom of the glass; fire carefully, and see that the quantity of fire is left at the end as at the beginning of the test. The evaporative power may be ascertained from the data obtained in the above test by the following rules:—

(*a*) *To find the number of cubic feet of water evaporated per hour.*—Multiply the number of square feet of water surface by the evaporation in inches of the gauge glass, multiply this product by 5, and divide the result by the number of minutes occupied in evaporation.

(*b*) *To find the quantity of water in pounds evaporated per pound of coal.*—Multiply the number of cubic feet of water evaporated per hour by 62·5 and divide the product by the quantity of coal in pounds consumed per hour.

Heating surface.—The evaporative power of a boiler depends upon the efficiency of its heating surface, the values of which are as follows:—

All horizontal surface above the flame	$= 1$
Vertical surface	$= \frac{1}{2}$
Tubes and round flues	$= 1\frac{1}{2}$ of their diam.
Convex surfaces above the flames	$= 1\frac{1}{6}$ of their diam.

Horizontal surfaces beneath the flame are of no value as heating surface.

(*c*) *To find the number of gallons of water a boiler will hold.*—For plain cylindrical boiler without tubes multiply the square of the diameter in feet by the length and by 4·89; the result would be the number of gallons required.

(*d*) *To find the number of gallons of water in a Cornish or Lancashire boiler.*—Multiply the sectional area of the shell in inches by the length of the shell in inches; multiply the combined sectional area of the flues in inches, by their length in inches; subtract this product from the first, and divide the remainder by 1728; the result is number of cubic feet, which multiplied by 6·24 will give the contents in gallons.

An insufficient supply of air causes imperfect combustion, an excessive supply, a waste of heat.

The following formula for finding the area of chimneys for stationery boilers is found very useful:—

Q = lbs. of coal consumed per hour.
H = Height of chimney in feet.
P = Indicated (not nominal) Horse Power of engine.
A = Area of top of chimney in square inches.

$$A = \frac{15\,Q}{\sqrt{5}} \text{ or } \frac{15\,Q\,P}{\sqrt{H}}.$$

Boiler Lagging.—To prevent radiation the exposed parts of steam boilers should always be covered with non-conducting composition. About 2 inches thick should be first applied, then wire netting of large mesh should be closely tied round and a final ½ inch of composition applied. When quite dry a coat of coal-tar should be applied.

Advantage of heating Feed water.—1 pound of water requires 160 units of heat to raise it from 52° F. to 212° F. and 1000 units of heat to evaporate it from and at 212° F. If therefore the feed water be raised to 212° F. by means of exhaust steam, 160 units will be saved and the resulting economy will be $\frac{160 \times 100}{1000+160} = 13{\cdot}8$ % gain.

Design of Tall Chimneys.

The stability of tall chimney stacks depends upon the weight of the brick work of the shaft and the pressure of the wind upon the outer surface.

The effective wind pressure on the face of a tall chimney varies considerably with the section of the stack. Colonel Moore gives the following table of coefficients to be applied in calculating the effective wind pressure on the faces of various solids.

COEFFICIENTS OF EFFECTIVE WIND PRESSURE ON SOLIDS.

Solid.	K.	Wind acting.
Sphere	·31	....
Cube	·81	Normal to face.
,, ...	·66	Parallel to diagonal of face.
Cylinder (height = Diam.) ..	·47	Normal to axis.
Cone (height = Diam. of base)	·38	Parallel to base.

K = Ratio of the effective pressure on a body to the pressure on a thin plate of area equal to the projected area of the body on a plane normal to the direction of the wind pressure.

The following effective horizontal wind pressure may be employed for chimneys of various sections:—

on a square chimney, 50 lbs. per sq. ft.
on a octagonal chimney 32 lbs. ,, ,,
on a circular chimney 25 lbs. ,, ,,

Let W = weight of brickwork in tons above any horizontal section.
A = area of horizontal section in square feet.
I = moment of Inertia of horizontal section in feet units.
R = outside radius and r = inside radius in ft.
P = Total wind pressure in tons against surface of chimney above the horizontal section considered.
h = height in feet of centre of pressure of wind above the section.

Thus direct compression on section due to dead weight of brickwork $= \frac{W}{A}$ tons per sq. ft.

Bending moment due to wind pressure = $P \times h$ foot-tons.

Stress due to bending $= \pm \frac{P \times h \times R}{I}$ tons per sq. ft.

The plus sign denoting compression at the lee-ward face and the minus sign tension at the wind-ward face of the section. The tensile stress due to the bending action of the wind pressure should not exceed the direct compression

due to the dead weight above any horizontal section. The stress should not be reduced to 0 on the windward face.

Example.—Tables (1) and (2) show the results of the application of the above rules to the design of circular chimneys 160 ft. and 150 ft. high respectively above ground level. The weight of brickwork is taken as 112 lbs. per. c.ft.

Table (1) Design of Brick Chimney, Height 160.'

Area in sq. ft.	Weight in tons.	Diameter. Outside.	Diameter. Inside.	Sectional Elevation.	I in foot units.	Projected wind area.	Compression in tons per sq. ft. Windward.	Compression in tons per sq. ft. Leeward.
		8'·3"	6'·0					
	41·9		7'·6¾"			282		
30·62		9'·9½"	6'·9¾"		294		·60	2·12
	64·5		8'·4½"			318		
46·54		11'·4½"	7·7½"		582		·42	4·16
	90·6		9'·2¼"			365		
65·18		12'·11½"	8·5¼"		1121		·41	5·63
	166·0		10'·6"			559		
89·91		15 0"	9'·9"		1885		·10	7·96
	237·0					473		
153·0		15·9"	9'·9"		4375		·94	6·90
	187·0							
576·0					27648			
	490·0							
784·0					51222			

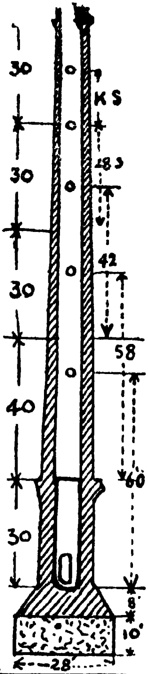
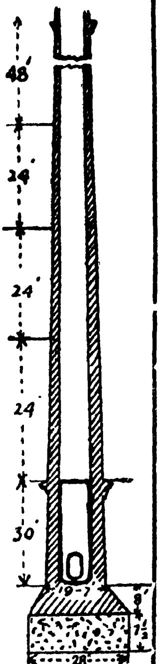


Table (2). *Design of a Brick Chimney, Height* 150′.

Area in sq. ft.	Weight in tons.	Diameter.		Sectional Elevation.	I in foot units.	Projected wind area.	Compression in tons per sq. ft.	
		Outside.	Inside.				Windward.	Leeward.
	38·37	7′·6″	4′·6″			192		
33·0					211		·61	1·71
	53·98					216		
			5′·9″					
44·93		9′·6″			346		·55	3·57
			5′·0″					
	70·44					240		
			6′·0″					
58·34		10′·6″			533		·37	5·23
			5′·3″					
	88·83					264		
			6′·3″					
73·21		11′·6″			784		·18	6·70
			5′·6″					
	90·07					238		
			6′·6″					
88·0		12′·6″			7057		·06	7·72
			5′·9″					
	427					535		
295·03		18′·0″	5′·7″		8830		1·38	3·90
784								
784								

45′ is an ordinary height to serve two steam boilers, but in some towns 90 ft. is minim, allowed. They are sometimes proportioned for height according to the coal burnt per week of 56 hours thus:—

4 tons per week	= 75 ft. high	50 tons per week	= 150 ft.
13 do.	= 100 do.	100 tons do.	= 180 ft.
20 do.	= 120 do.	150 tons do.	= 200 ft.

Consumption of Fuel.—The consumption of coal, per I. H. P. depends upon the boiler as well as the engine, say:—

Non-condensing Engine ..	3 lbs.	coal per I.H. P.	per hour.
Simple condensing	2 lbs.	do.	do.
Compound condensing ,,	1·75 lbs.	do.	do.
Triple compound ,,	1·5 lbs.	do.	do.
Quadruple compound Engine	1·25 lbs.	do.	do.

Sizes of Manholes in Boilers.

12″ × 8″ can be entered by a boy.
13″ × 9″ do. do. lad.
14″ × 10″ do. do. average man.
15″ × 12″ do. do. stout man.

Causes of Priming.

(1) Changes in density of feed water from fresh to salt or *vice versa*.
(2) Rapid extraction of steam after perfect rest.
(3) Sometimes sudden starting of engine.
(4) Feeding with muddy water or water contaminated with sewage.
(5) Steam space too limited.
(6) Defective circulation in boiler.
(7) Hard firing.

Factor of Safety Steam Boilers.

Test pressure = ⅓ ultimate strength.
Working pressure if under periodical inspection = ⅕ ultimate strength.
Working pressure if not under independent inspection = ⅙ ultimate strength.
In estimating ultimate strength ample allowance should be made for defects in design or workmanship.

Cooling Towers.

Cooling towers are employed where condensing water cannot be obtained in sufficient quantity. The circulating water is broken up into sprays or thin sheets and falls through a current of air. The air in becoming warmer, takes up heat from the water, evaporation also takes place and tends to saturate the air. This evaporation is ·8 to ·95 per lb. of steam exhaust to the condensers. The distance between spray outlets and tank under the tower is usually about 25 ft. The towers are 50 to 80 ft. high for natural draft, but may be shorter if forced draft fan is used. The ground area required is 1 sq. ft. per 20 lbs. steam condensed per hour approx. The circulating water required is 70 gallons per sq. ft. of ground area, cooled from 95° to 75°. The circulating water required is 25 to 30 lbs. per sq. ft. per hour. If forced draft is used, the fan requires ·3 per cent. to ·5 per cent. of the H. P. of the main unit.

Cornish and Lancashire Boilers (Havrez).

D = Diameter of boiler in inches.

d = Diameter of flues in inches.

L = Length of shell of boiler in feet.

l = Length of fire grates in inches.

H = Nominal horse-power at 16·9 square feet per H. P.

p = Effective pressure in atmospheres.

W = Total weight of boiler in lbs.

In Cornish Boilers:—

Space between underside of flue and shell 4 to 6 inches.

Depth of water over flue „ „ 4 to 8 „

Cornish Boilers.	Lancashire Boilers.
$D = 1{\cdot}7d$	$D = 2{\cdot}5d$
$D = 11{\cdot}42\sqrt{H}$	$D = 11{\cdot}4\sqrt{H}.$
$d = 6{\cdot}72\sqrt{H}$	$d = 4{\cdot}56\sqrt{H}.$
$l = 11{\cdot}8\sqrt{H}$	$l = 8{\cdot}65\sqrt{H}.$
$L = 5{\cdot}1\sqrt{H}$	$L = 14{\cdot}4 + 0{\cdot}46\ H.$
$W = H(110 + 22\,p\sqrt{H})$	$W = H(220 + 12{\cdot}35\,p\sqrt{H}).$

And area of chimney, $15\frac{1}{2}$ square inches per horse-power.

Table showing diameter of shell and flue and length and weight of boilers:—

Nominal Horse Power.	Cornish Boilers.				Lancashire Boilers.			
	Diameter of Shell.	Diameter of Flue.	Length of Boiler.	Weight of Boiler.	Diameter of Shell.	Diameter of Flue.	Length of Boiler.	Weight of Boiler.
10	36 in.	$21\frac{1}{4}$ ins.	16·1 ft.	2·04 tons	..	..	..	..
20	51 „	30 „	22·8 „	5·37 „	..	..	..	..
30	$62\frac{1}{2}$ „	$36\frac{3}{4}$ „	28 „	9·54 „	$62\frac{1}{2}$ ins.	25 ins.	28·2 ft.	7·48 tons
40	$72\frac{1}{4}$ „	$42\frac{1}{2}$ „	32·3 „	14·39 „	72 „	$28\frac{3}{4}$ „	32·8 „	10·90 „
50	$80\frac{3}{4}$ „	$47\frac{1}{2}$ „	36 „	19·82 „	$80\frac{1}{2}$ „	$32\frac{1}{4}$ „	37·4 „	14·66 „
60	$88\frac{1}{2}$ „	52 „	39·5 „	25·77 „	$88\frac{1}{4}$ „	$34\frac{1}{2}$ „	42 „	18·72 „

Pressure assumed at 5 atmospheres effective or 6 atmospheres absolute.

COMBINED FURNACE AND BOILER EFFICIENCIES.

B. T. U. per lbs. of dry coal.	50%		60%		70%		80%	
	Evaporation per lbs. of coal.	lbs. coal per boiler H.P. hour.	Evaporation per lbs. of coal.	lbs. coal per boiler H. P. hour.	Evaporation per lbs. of coal.	lbs. coal per boiler H. P. hour.	Evaporation per lbs. of hour.	lbs. coal per boiler H. P. hour.
8,000	4·142	8·33	4·97	6·94	5·80	5·96	6·28	5·20
9,000	6·66	7·41	5·59	6·18	6·52	5·28	7·46	4·63
10,000	5·224	6·60	6·27	5·50	7·31	4·72	8·36	4·13
11,000	5·695	6·06	8·34	5·05	7·97	4·33	9·11	3·79
12,000	6·213	5·56	7·46	4·63	8·70	3·97	9·94	3·47
13,000	6·731	5·12	8·08	4·27	9·42	3·66	10·77	3·20
14,000	7·249	4·76	8·70	3·97	10·15	3·40	11·60	2·98
14,500	7·508	4·60	9·01	3·83	10·51	3·28	12·01	2·87

The value of good Indian coal ranges from 8,000 to 10,000 B. T. U. per lb. of coal.

Weight of Rim of Flywheel.

$$W = \text{Weight of fly wheel rim} = \frac{KHP}{V^2R}$$

Where R = Revolutions per minute.
V = Velocity of rim in feet per second.
HP = Actual Horse-power.
K = 16,000,000 for lbs. = 143,000 for cwts. = 7,140 for tons.

When there is a great irregularity of load or very high expansion, or extreme uniformity is required, multiply K by 1·5 or even by 1·8 in extreme cases.

The usual diameter of a fly-wheel is from 3½ to 4 times the stroke of the engine, but in corn-mills or heavy machinery rotating at high velocity, the velocity of the periphery must exceed the velocity of the periphery of the stones or machinery, to prevent back lash.

Maximum safe velocity of rims of cast-iron fly wheels is 80 feet per second. This may be increased to 90 feet in small wheels cast in one piece.

French Horse-power *Force-de-cheval.*

1 French H. P. = 75 kilogram meters (542·486) ft. lbs. per second.
1 *Force-de-cheval* = ·98638 H. P.
1 H. P. = 1·01385 *Force-de-cheval.*

PORTABLE OIL ENGINES.

TABLE OF SIZES, DIMENSIONS AND WEIGHTS.

B.H.P. Max. Crude Oil.	B.H.P. Max. Refined Oil.	Revs. per minute	Pulley for driving Thrasher Diam.	Pulley for driving Thrasher Width	Road Wheels Hind. Diam.	Road Wheels Hind. Width	Road Wheels Fore. Diam.	Road Wheels Fore. Width	Approximate Weight Cwts. Net.	Price Approximate.
			in.	in.	in.	in.	in	in.		
10	11	450	17 ×	6	30 ×	5	24 ×	4	25	2400
16	17½	380	20 ×	6½	30 ×	5	24 ×	4	34	3250
22	24	360	22 ×	7	39 ×	6	30 ×	5	45	4050
28	31	340	24 ×	8	39 ×	6	30 ×	5	55	5600

NON-CONDENSING ENGINES, WITH VERTICAL BOILERS.

	Nominal Horse-power. 2	4	6	8	10	12
Diameter of boiler ..	2′·6″	3′·3″	3′·9″	4′·6″	4′·9″	5′
Height of boiler ..	5′	6′·9″	8′·0″	8′·6″	10′·0″	11′
Diameter of cylinder ..	5″	7″	9″	10″	11″	12″
Length of stroke ..	8″	10″	11″	12″	13″	14″
Revolutions per min. ..	200	150	135	125	115	110
Weight packed in tons	1¼	2½	2¾	5	6½	7¾
Price, Rs. ..	2,000	3,700	4,500	5,000	6,000	7,000

PORTABLE ENGINES (SINGLE CYLINDER).

(100 lbs. Pressure).

	Nominal Horse Power. 4	6	8	10	12
Diameter of cylinder inch ..	6½	8	9	10	12
Length of stroke inch ..	10	12	13	14	15
Revolutions per minute ..	165	140	140	140	130
Approx. weight in tons, packed	3	4¾	5¼	6¾	7½
Price, Rs. ..	5,000	4,380	5,100	5,800	6,700

Portable Engines (Double Cylinder).

100—115 lbs. Working Pressure.

	Nominal Horse-power.				
	10	15	20	25	30
Diameter of cylinder in inches ..	7	9	10	12	13
Stroke in inches ..	12	14	14	18	18
Revolutions per minute ..	140	125	125	110	110
Weight packed in tons ..	6¼	9½	10½	15¼	18
Price, Rs. ..	6,400	8,500	10,800	13,000	15,400

Extra on above for colonial type boiler (which can burn wood) at Rs. 21 per N. H. P. extra.

Useful Practical Hints for Engineers.

Oil Engines.—Allow 5% loss of power for every 1,000 ft. rise above sea level. Allow 1% loss of power for every 5 degrees F. rise in temperature above 65° F. Allow at least 20 gallons of cooling water per B. H. P. hour at about 90° F. Insufficient cooling water results in loss of power.

Use only the best quality lubricating oil. The consumption of this should not exceed 5% of the quantity of fuel oil consumed when working at full load (no reduction at light loads).

Portable Steam Engines.

One N. H. P. is equal to about 4 B. H. P. maximum, (but for economical working 3½ times); coal should be slightly damped when firing these boilers. Do not allow the exhaust steam to go directly into the feed water otherwise oil is fed into the boiler causing priming. If you wish to utilize the exhaust steam put in a feed water heater.

When working with an injector do not let the temperature of the feed water exceed 110° F.

Vertical Boilers.

When selecting a vertical boiler for supplying steam to an engine allow for an additional 10% over and above the quantity of steam calculated according to the steam consumption of the engine. Carefully adjust the damper to avoid excessive coal consumption.

Slide Valve Steam Engines.

Approximate steam consumption when running non-condensing 33 lbs. per I. H. P. per hour with a good jet condenser the consumption is about 28 lbs. per I. H. P. hour.

The approximate quantity of cooling water required for a condenser is 35 gallons per I. H. P. per hour.

Lubricants for Various Cases.

(1) Under very great pressure with slow speed:—
Graphite, soapstone, tallow and other greases.

(2) Under heavy pressure and high speed:—
Sperm oil, castor oil and heavy mineral oils.

(3) Under light pressure and high speed:—
Sperm oil, refined petroleum, olive, rape and cotton seed oil.

(4) Ordinary machines, Lard oil, heavy mineral and other vegetable oils.

(5) Steam cylinders:—Heavy mineral oils.

(6) For lubricating the dies in a screwing machine cheap mineral oil is generally used.

(7) To lubricate turning and milling tools working on wrought iron or mild steel, a mixture of oil, soft soap and water is used—*Adams.*

Cylinder Lubrication.

Animal and vegetable fats and oils are easily decomposed by high pressure steam into acids having a corrosive effect on metal and hence should not be used. A good cylinder oil should have a specific gravity of about ·9 at 60° F. flash point 550° F. For gas engines and high pressure steam engines worked with super-heated steam a pure hydro carbon oil of very high flash point should be used. Always consult the manufacturer's instructions.

FACTORIES.

Number of Teeth in Wheels.

If N = number of teeth in driving wheel.

n = number of teeth in driven wheel.

V = Revolutions of driving wheel.

v = Revolutions of driven wheel.

Then $n = \frac{N\,V}{v}$ and $v = \frac{N\,V}{n}$.

Leather Belting.

To find the Horse Power transmitted by leather belt.—Multiply speed in feet per minute by width in inches and divide by 3,3000, let the result be R.

50 R = H. P. transmitted by single belt.

66 R = H. P. transmitted by light double belt.

80 R = H. P. transmitted by heavy double belt.

Approximate Horse Power transmitted by leather belting for every 100 ft. velocity per minute.

Width in inches.	Single.	Light double.	Heavy double.	REMARKS.
3	·45	·60	·75	Velocity in ft. per minute $V = \pi$ Dn. where D = diameter of fly wheel or pully in feet n = revolutions per minute. $\pi = \frac{22}{7}$ approx.
4	.60	·80	1·00	
5	·75	1·00	1·25	
6	·90	1·20	1·65	
7	1·05	1·10	1·80	
8	1·20	1·60	2·00	
9	1·35	1·80	2·25	
10	1·50	2·00	2·55	
11	1·65	2·20	2·75	
12	1·80	2·40	3·3	
14	..	2·80	3·85	
16	..	3·20	4·4	
18	..	3·60	4·95	
20	..	4·00	5·50	

Useful Hints.

(1) One H. P. will be transmitted by a single thickness belt one inch wide running at the speed of 1,000 ft. per minute.

(2) A belt $\frac{3}{10}$ths of a square inch section will transmit one H. P. at the foregoing rate.

(3) It is safe to reckon that a double belt will do half as much work again as a single one.

(4) A double belt should not be used upon pulleys whose diameters are less than about 3 times the width of the belt.

(5) Rubber belts will transmit from 25 to 40 per cent. more H. P. than leather belts.

(6) Long belts are more effective than short ones.

Approximate Weight of Leather Belting in lbs. per 100 ft. in length.

HEAVY DOUBLE LEATHER BELTS.

Width in inches.	3	4	5	6	7	8	9	10	12
Double belts, medium	53	76	92	110	135	160	186	215	265
,, ,, strong	59	83	100	120	145	172	200	230	280

SINGLE LEATHER BELTS.

Width in inches.	3	4	5	6	7	8	9	10	12
Single belts, medium ..	29	41	52	64	75	89	103	118	150
,, ,, strong ..	31	43	55	67	79	94	109	125	160

HORSE POWER OF COTTON DRIVING ROPES.

Velocity in ft. per minute.	Diameter of rope in inches.								
	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
1000	2·5	3·5	4·5	5·7	7·1	8·6	10·2	14·0	18·2
1500	3·7	5·4	6·7	8·5	10·6	12·9	15·3	21·0	27·1
2000	5·1	7·0	9·1	11·5	14·2	17·3	20·5	28·0	36·5
2500	6·2	8·4	11·0	13·9	17·2	20·8	24·7	33·7	44·0
3000	7·1	9·6	12·6	16·0	19·8	23·9	28·4	38·7	50·4
3500	7·8	10·7	13·9	17·6	21·8	26·4	31·4	42·8	55·8
4000	8·4	11·4	14·8	18·7	23·2	28·1	33·4	45·5	59·4
4500	8·7	11·7	15·3	19·4	24·0	29·0	34·5	47·0	61·4
5000	8·7	11·8	15·4	19·4	24·1	29·1	34·6	47·1	61·5
5500	8·4	11·4	14·8	18·8	23·2	28·1	33·4	45·5	59·4

Velocity in feet per minute $= \frac{22}{7} \times$ diameter of flywheel or pulley $\times$ No. of revolutions per minute.

Tho above table has been calculated by the following formula :—

Let D = Diameter of rope in inches.

S = Speed of rope in feet per second.

T = Total Str ss allowed in lbs.

E = Effective Stress in lbs.

W = Weight of one foot of rope in lbs. (the weight per foot has been taken as equal to ·27 D^2 lbs.).

Assume T to be $160D^2$. In order to obtain the Effective Stress (E) the loss due to Centrifugal Tension has to be deducted from the Total Stress.

Centrifugal Tension in lbs. $= \frac{S^2 \times W}{32}$.

The H. P. can now be calculated by the formula

$$H. P. = \frac{S \times E}{550}.$$

Useful Hints.

(1) Take care that the ropes do not get wet; water is harmful.

(2) Take care that ropes a not rub on anything in their flight, either when running at full speed or when starting and stopping the engine.

(3) Take care that ropes do not slip; if they slip they are probably overloaded, or are too small for the grooves.

(4) All ropes should be lubricated with a good anti-fraying and lubricating composition. Black lead mixtures should not be used.

(5) The minimum diameter of the smallest pulley should be 30 times the rope diameter. The most satisfactory drives are obtained with rope speeds of about 3,600 to 5,000 ft. per minute.

Advantages of Rope Driving.

1.—The question of first cost; also that of renewals. Rope Driving is very much cheaper than Electrical Installations, Belts or Gearing.

2.—Saving in size of Pulleys and driving space; a rope 1½ in. diameter will transmit as much power as a belt 6 in. wide.

3.—Freedom to drive shafts at almost any desired distance apart, and with almost any variation in speed.

4.—Slipping reduced to a minimum, and easier distribution of power.

5.—Elasticity; adding to the safety of the driving, thereby reducing stoppages.

6.—Lighter running, less noise, and more positive drive.

7.—Freedom from stoppage or breakdown. If it should happen that a rope gives way at any time, it can be easily removed, the remaining ropes doing the work until stopping time, or such time as the rope can be repaired or a new one put on in its place.

8.—Rope drives may be substituted for heavy leather belts and trained to any angle.

Pulleys for Rope Driving.

Manila Rope	1¼″	diam. on	3 ft.	pulley will transmit	5 I. H. P.
,, ,,	1½″	,, ,,	4 ft.	,, ,, ,,	8 I. H. P.
,, ,,	1¾″	,, ,,	5 ft.	,, ,, ,,	11 I. H. P.
,, ,,	2″	,, ,,	6 ft.	,, ,, ,,	15 I. H. P.

(*James Combe.*)

The pulleys should not be less in diameter than (circumference of rope)^2 × 3.

For rope driving the sides of groove make an angle of 10° with each other down to the semi-diameter, and 45° below, the bottom of the groove being curred with a radius of ⅜ diameter of rope, with a clearance of ¼ diameter.

Transmitting Power by Wire Ropes.

(*a*) For ropes made of 7 wire strands the diameter of pulley should be about 150 times the diameter of rope.

(*b*) For ropes made of 12 wire strands the diameter of pulley should be about 115 times the diameter of rope.

(*c*) For ropes made of 19 wire strands the diameter of pulley should be about 150 times the diameter of rope.

Provided the driving and driven pulleys are of equal and not less diameters than given in the following Tables, the horse power each rope will transmit is approximately 3 times the square of the diameter of rope in inches multiplied by the velocity in ft. per second.

Diam. of rope inches.	7 wire strand ropes.	12 wire strand ropes.	19 wire strand ropes.	Horse power of wire ropes at velocities given in ft. per second.							
	Smallest diameters of pulleys which should be used.										
	Diam. in inches.	Diam. in inches.	Diam. in inches.	10	20	30	40	50	60	70	80
⅜	54	42	36	4½	9	13½	18	22½	27	31½	36
½	72	60	48	8	16	24	32	40	48	56	64
⅝	96	72	60	12	24	36	48	60	72	84	96
¾	108	84	72	17	35	52	70	87	104	122	140
⅞	132	96	84	24	48	72	96	120	144	168	192
1	114	120	96	31	62	93	124	155	186	217	248

TABLES FOR ASCERTAINING THE PULL ON A HAULAGE ROPE FOR VARIOUS INCLINES.

Table for Gradual Inclines.				Table for Steep Inclines.			
Incline A.	Angle B.	Multiple for Load C.	Multiple for Friction D.	Angle E.	Incline F.	Multiple for Load G.	Multiple for Friction H.
1 in 100	0°—34′	·01	1·0	10°—0′	1 in 5·67	·174	·985
„ 95	0 —36	·01	1·0	12—30	„ 4·51	·216	·976
„ 90	0 —38	·011	1·0	15—0	„ 3·73	·259	·966
„ 85	0 —40	·012	1·0	17—30	„ 3·17	·301	·954
„ 80	0 —43	·012	1·0	20—0	„ 2·75	·342	·940
„ 75	0 —46	·013	1·0	22—30	„ 2·41	·383	·924
„ 70	0 —49	·014	1·0	25—0	„ 2·14	·423	·906
„ 65	0 —53	·016	1·0	27—30	„ 1·92	·462	·887
„ 60	0 —57	·017	1·0	30—0	„ 1·73	·500	·866
„ 55	1 — 3	·018	1·0	32—30	„ 1·57	·537	·843
„ 50	1 — 9	·020	1·0	35—0	„ 1·43	·574	·819
„ 45	1 —16	·022	1·0	37—30	„ 1·30	·609	·793
„ 40	1 —26	·025	1·0	40—0	„ 1·19	·643	·766
„ 35	1 —38	·029	1·0	42—30	„ 1·09	·676	·737
„ 30	1 —54	·033	1·0	45—0	„ 1·00	·707	·707
„ 25	2 —18	·040	1·0	47—30	„ ·92	·737	·675
„ 20	2 —52	·050	1·0	50—0	„ ·84	·766	·643
„ 18	3 —11	·056	1·0	52—30	„ ·77	·793	·609
„ 16	3 —35	·063	1·0	55—0	„ ·70	·819	·574
„ 14	4 —5	·072	1·0	57—30	„ ·64	·843	·537
„ 12	4 —46	·083	1·0	60—0	„ ·58	·866	·500
„ 10	5 —43	·100	1·0	62—30	„ ·52	·887	·462
„ 9	6 —20	·110	1·0	65 —0	„ ·47	·906	·423
„ 8	7 —7	·124	1·0	67—30	„ ·41	·924	·383
„ 7	8 —8	·142	·98	70 —0	„ ·36	·940	·342
„ 6	9 —28	·164	·98	72 —30	„ ·32	·954	·300
„ 5	11 —19	·196	·98	75 —0	„ ·27	·966	·259
„ 4	14 — 2	·243	·97	77 —30	„ ·22	·976	·216
„ 3	18 —26	·316	·95	80 —0	„ ·18	·985	·174
„ 2	26 —34	·447	·89	85 —0	„ ·09	·996	·087
„ 1	45 —0	·707	·71	90 —0	„ ·00	1·000	·000

Multiply the sum of the weights of the Load, the Truck, and the full weight of Rope (when truck is at the bottom of the incline) by the figure in column C or G, corresponding to the incline. The answer is the nett pull on the rope regardless of friction. Allowance for friction may be taken at from 15% to 30%, according to the condition of the track. The frictional resistance of the track decreases as the incline becomes more acute, it therefore follows that the percentage allowed for friction will be reduced. To meet this condition the multiples given in column D and H may be resorted to.

(1) *Example.*—A load of 60 cwt. is to be hauled along an incline of 1 in 9, What is the pull on the rope ?

Pull on rope resulting from the incline.

Weight of the load in the truck		60 cwt.
„ „ truck	.. say	30 „
„ „ rope	.. „	5 „
	Total	95 cwt.

Load multiple in column C for an incline of 1 in 9 = ·110, this multiplied by 95 gives $95 \times ·110 = 10·45$ cwt. pull on rope.

Amount to be added for friction. Assume a track in fairly good condition, for which 25% is estimated as covering loss due to friction. The multiple in column D is 1 so the percentage remains unchanged, and 25% of 10·45 $= \frac{25}{100} \times 10·45 = 2·61$ cwt.

Total pull on rope.

Pull due to incline	..	10·45 cwt.
„ „ friction	..	2·61 „
	Total pull	13·06 „

(2) *Example.*—A load of 60 cwt. is to be hauled up an incline of 40°. Find the pull on the rope.

Pull on rope resulting from the incline.

Weight of the load in the truck		60 cwt.
„ „ truck	.. say	30 „
„ „ rope	.. „	12 „
	Total ..	102 „

Load multiple in column G for an incline of 40° = ·643, this multiplied by 102 gives $102 \times ·643 = 65·58$ cwt. pull on rope.

Amount to be added for friction. Assume a track in good condition for which 20% is estimated as covering loss due to friction. The multiple in column H is ·766, and $20 \times ·766 = 15·32$, say 15% and 15% of 65·58 $= \frac{15}{100} \times 65·58 =$ 9·83 cwt.

Total pull on rope.

Pull due to incline	..	65·58 cwt.
„ „ friction	..	9·83 „
	Total pull	75·41 cwt.

Having ascertained the pull on the rope, the equivalent horse-power may be obtained as follows :—

(1) EXAMPLE.—Assuming a rope speed of 4 miles per hour : 4 × 5,280 = 21,120 feet per hour ÷ 60 = 352 feet per minute.

13·06 cwt. = 1,462 lbs. ; × 352 gives 515,000 foot-pounds

$$\text{per minute, and } \frac{515,000}{33,000} = 15{\cdot}6 \text{ h. p.}$$

(2) EXAMPLE.—Assuming a rope speed of 2 miles per hour ; 2 × 5280 = 10,560 feet per hour ÷ 60 = 176 feet per minute.

75·41 cwt. = 8446 lbs. ; × 176 gives 1,486,500 foot pounds

$$\text{per minute, and } \frac{1,486,500}{33,000} = 45 \text{ h. p.}$$

Formula for the Horse Power which Mild Steel Shafts of good quality will transmit at various speeds.

For HEAD SHAFTS which are well supported :—

Multiply the cube of the diameter of the shaft by the revolutions per minute and divide the product by the constant 100.

For LINE SHAFTS, well supported, from which power is being taken at frequent intervals along its length, such as obtains in Machine Shops, Engineering Works, Textile Factories, etc. :—

Multiply the cube of the diameter of the shaft by the revolutions per minute and divide the product by the constant $66\frac{2}{3}$.

For TRANSMISSION SHAFTS, well supported in bearings for transmitting power only, and not subject to any transverse strain, also for short countershafts supported at short centres, and where the pull of belts, ropes, etc., come close to bearings :--

Multiply the cube of the diameter of the shaft by the revolutions per minute and divide the product by the constant 50.

TABLE OF DIAMETERS, CUBES OF DIAMETERS AND HORSE POWERS AT ONE REVOLUTION PER MINUTE.

Shaft Diameters ..	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.
Cubes of Diameters ..	3·375	5·36	8	11·39	15·62	20·79	27	34·32	42·87
Head Shafts—H. P. per Rev. ..	·033	·053	·080	·113	·156	·207	·270	·343	·428
Line Shafts—H. P. per Rev. ..	·050	·083	·120	·170	·234	·311	·405	·514	·643
Transmission Shafts—H. P. per Rev. ..	·067	·107	·160	·227	·312	·415	·540	·686	·857

Shaft Diameters ..	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5½ in.	6 in.	6½ in.
Cubes of Diameters ..	52·73	64	76·76	91·12	107·17	125	166·37	216	274·62
Head Shafts—H. P. per Rev. ..	·527	·640	·767	·911	1·071	1·250	1·663	2·160	2·746
Line Shafts—H. P. per Rev. ..	·791	·960	1·151	1·366	1·607	1·875	2·495	3·240	4·119
Transmission Shafts—H. P per Rev. ..	1·054	1·280	1·535	1·822	2·143	2·500	3·327	4·320	5·492

Shaft Diameters ..	7 in.	7½ in.	8 in.	8½ in.	9 in.	9½ in.	10 in.	10½ in.	11 in.	12 in.
Cubes of Diameters ..	343	421·87	512	614·12	729	857·37	1000	1157·62	1331	1728
Head Shafts—H. P. per Rev. ..	3·430	4·218	5·120	6·141	7·290	8·573	10·00	11·655	13·310	17·280
Line Shafts—H. P. per Rev. ..	5·145	6·328	7·680	9·211	10·935	12·860	15·00	17·482	19·965	25·92
Transmission Shafts—H. P. per Rev. ..	6·860	8·437	10·24	12·282	14·58	17·147	20·00	23·31	26·62	34·56

Shafts receiving motion from Gas or Oil Explosive Engines or which are subject to heavy intermittent or shock loads, or vibration of Gear Wheels should not be of less proportions than the dimensions determined by the formula for Head Shafts. The power of Wrought-Iron Shafts may be taken as 15 to 20 per cent. less than good quality Mild Steel.

Diameters in Inches of Wrought-iron Shafts.

Horse power.	Number of Revolutions per Minute of Wrought-iron Shafts.												
	10	20	40	60	80	100	200	300	400	500	600	800	1000
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1	2·32	1·84	1·46	1·28	1·16	1·08	0·85	0·75	0·68	0·63	0·59	0·54	0·5
2	2·92	2·32	1·84	1·61	1·46	1·35	1·08	0·94	0·86	0·80	0·75	0·68	0·63
3	3·40	2·66	2·11	1·71	1·67	1·55	1·24	1·08	0·98	0·91	0·86	0·78	0·72
4	3·68	2·92	2·32	1·80	1·84	1·71	1·36	1·19	1·08	1·00	0·94	0·86	0·80
5	3·97	3·15	2·50	1·88	1·99	1·84	1·46	1·28	1·16	1·08	1·02	0·92	0·86
6	4·22	3·35	2·66	2·06	2·11	1·96	1·56	1·36	1·24	1·15	1·08	0·98	0·91
7	4·44	3·52	2·80	2·12	2·22	2·06	1·64	1·43	1·30	1·21	1·14	1·03	0·96
8	4·64	3·69	2·92	2·27	2·33	2·15	1·71	1·49	1·36	1·26	1·19	1·08	1·00
9	4·82	3·83	3·04	2·40	2·42	2·24	1·78	1·55	1·41	1·31	1·24	1·12	1·04
10	5·00	3·98	3·15	2·75	2·50	2·22	1·85	1·61	1·47	1·36	1·28	1·16	1·08
20	6·30	5·00	3·97	3·47	3·15	2·92	2·33	2·03	1·84	1·71	1·61	1·46	1·36
30	7·21	5·72	4·54	3·97	3·61	3·34	2·66	2·33	2·11	1·96	1·84	1·68	1·55
40	7·94	6·30	5·00	4·37	3·98	3·68	2·92	2·56	2·33	2·15	2·03	1·85	1·71
50	8·55	6·79	5·38	4·71	4·28	3·97	3·15	2·75	2·50	2·33	2·19	1·99	1·84
60	9·08	7·21	5·72	5·08	4·55	4·21	3·35	2·93	2·66	2·47	2·33	2·11	1·96
70	9·57	7·59	6·03	5·27	4·79	4·44	3·53	3·06	2·80	2·60	2·44	2·22	2·00
80	10·0	7·94	6·30	5·51	5·00	4·64	3·63	3·22	2·93	2·71	2·55	2·33	2·15
90	10·4	8·25	6·55	5·73	5·20	4·82	3·83	3·35	3·04	2·82	2·61	2·42	2·24
100	10·8	8·55	6·78	5·93	5·39	5·00	3·97	3·47	3·15	2·92	2·75	2·50	2·31
140	12·0	9·57	7·59	6·64	6·03	5·59	4·44	3·88	3·52	3·27	3·08	2·80	2·59
180	13·1	10·4	8·26	7·21	6·55	6·08	4·83	4·22	3·83	3·56	3·35	3·04	2·82
200	13·6	10·8	8·55	7·48	6·79	6·30	5·00	4·37	3·97	3·68	3·47	3·15	2·92
250	14·6	11·6	9·22	8·06	7·32	6·78	5·39	4·70	4·27	3·97	3·73	3·39	3·15
300	15·5	12·3	9·80	8·57	7·77	7·21	5·73	5·00	4·54	4·11	3·97	3·61	3·35
350	16·3	13·0	10·3	9·00	8·18	7·59	6·03	5·41	4·78	4·41	4·28	3·80	3·52
400	17·1	13·6	10·8	9·42	8·55	7·94	6·30	5·50	5·00	4·64	4·37	3·92	3·68
450	17·8	14·1	11·2	9·80	8·89	8·26	6·55	5·72	5·20	4·83	4·54	4·13	3·88
500	18·4	14·6	11·6	10·1	9·21	8·55	6·79	5·93	5·39	5·00	4·71	4·27	3·97
550	19·0	15·1	12·0	10·5	9·50	8·82	7·01	6·12	5·56	5·16	4·86	4·41	4·10
600	19·6	15·5	12·3	10·8	9·79	9·08	7·21	6·30	5·72	5·32	5·00	4·54	4·22
700	20·7	16·4	13·0	11·4	10·3	9·56	7·59	6·63	6·03	5·59	5·26	4·78	4·44
800	21·5	17·1	13·6	11·9	10·8	10·0	7·94	6·93	6·30	5·85	5·50	5·00	4·64
1000	23·3	18·5	14·6	12·8	11·6	10·8	8·55	7·47	6·79	6·30	5·93	5·39	5·00

Approximate Centre Distance apart of Bearings for Shafting Carrying Normal Loads.

TRANSMISSION SHAFTING

FOR TRANSMITTING POWER ONLY.

Approximate limit of distance apart of Centres of Bearings for Shafts which do not carry any Pulley, Gears, etc.

Dia. of Shaft in Inches.	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5	5½	6
Revs. per Minute.	Distance between Bearing Centres in feet.													
100	9	10	11	11½	12	12½	13	13½	14	14½	15	16	17	18
150	8½	9½	10¾	11¼	11¾	12	12½	13	13½	14	14½	15½	16½	17½
200	8	9	10½	10¾	11¼	11½	12	12½	13	13½	13¾	14¾	15¾	16¾
250	7½	8½	10	10¼	10¾	11	11½	12	12¼	12¾	13¼	14	15	16
300	7	8	9½	9¾	10	10¼	10¾	11	11	12	12½	13¼	14	15
350	6¾	7¾	8¾	9	9¼	9½	10	10½	10¾	11	11¼	12¼	13	13¾
400	6¼	7¼	8	8¼	8½	9	9¼	9½	10	10¼	10½	11¼	12	12½
500	5¾	6¾	7½	7¾	8	8½	9	9¼	9½	9¾	10	10½	11	11½
600	5¼	6¼	7	7¼	7½	8	8½	9	9¼	9½	9¾	10	10½	11
700	4¾	5¾	6½	6¾	7	7½	8	8½	8¾	9	9½	9¾	10	
800	4½	5¼	6	6¼	6½	7	7½	8	8½	8¾	9	9¼		
1,000	4	4¾	5½	5¾	6	6½	7	7½	8					

Approximate Centre Distance apart of Bearings for Shafting Carrying Normal Loads.

LINE SHAFTING

Carrying Pulleys, etc.

Approximate limit of distance apart of Centres of Bearings for Shafts which do not carry more than an average number of pulleys transmitting normal powers.

Dia. of Shaft in Inches.	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5	5½	6
Revs. per Minute.	Distance between Bearing Centres in feet.													
100	7¼	7½	8	8½	9	9½	10	10½	11	11½	12	13	14	15
150	6¾	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	11¾	12¾	13¾	14½
200	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12¼	13¼	14
250	6	6¾	7¼	7¾	8¼	8¾	9¼	9¾	10	10½	11	11¾	12½	13¼
300	5¾	6½	7	7½	8	8½	8¾	9¼	9½	10	10½	11	11¾	12½
350	5¼	6	6¾	7¼	7¾	8	8½	8¾	9	9½	9¾	10¼	11	11½
400	5	5¾	6½	7	7½	7¾	8	8¼	8½	8¾	9	9½	10	10½
500	4½	5½	6¼	6½	7	7½	7¾	8	8¼	8½	8¾	9¼	9½	10
600	4¼	5¼	6	6¼	6½	7	7¼	7½	8	8¼	8½	9	9¼	9½
700	4	4¾	5½	5¾	6	6½	7	7¼	7¾	8	8¼	8½	8¾	
800	3¾	4¼	5	5¼	5½	6	6½	7	7½	7¾	8	8¼		
1,000	3½	4	4½	4¾	5	5½	6	6½	7					

Maximum Speed of Gearing.

Ordinary Cast Iron Wheels	1,800	ft. per minute.
Helical Cast Iron Wheels	2,400	„ „
Mortise Cast Iron Wheels	2,400	„ „
Ordinary Cast Steel Wheels	2,600	„ „
Helical Cast Steel Wheels	3,000	„ „
Special Cast Iron Machine Cut Wheels ..	3,000	„ „
Double herring bone gears in oil ..	5,000	„ „

H. P. AND WORKING LOADS OF CUT CAST STEEL GEARS.

Diametral pitch.	Circular pitch.	No. of Teeth.	Speed of pitch line in feet per minute. 100		200		300		600		900		1,200	
			Working Load.	H. P.	Working Load.	H. P.	W. L.	H. P.	W. L.	H. P.	W. L.	H. P.	W. L.	H. P.
10	·3142	12	90	·27	79	·47	70	·63	53	·96	42	1·15	35	1·27
		20	120	·36	105	·63	94	·85	70	1·27	56	1·53	47	1·71
		40	145	·44	127	·76	113	1·02	85	1·55	68	1·86	56	2·04
		60	152	·46	133	·80	119	1·07	89	1·62	71	1·94	60	2·18
		130	160	·49	140	·84	124	1·12	94	1·71	74	2·02	62	2·26
8	·392	12	113	·34	98	·59	87	·78	66	1·20	52	1·42	44	1·60
		20	150	.45	130	·78	116	1·04	87	1·58	70	1·91	58	2·11
		40	180	·55	158	·95	141	1·27	105	1·91	84	2·29	70	2·54
		60	190	·58	165	·99	148	1·33	110	2·00	88	2·40	74	2·69
		130	200	·61	174	1·04	155	1·40	115	2·09	92	2·57	77	2·80
4	·785	12	225	·68	195	1·17	175	1·58	130	2·36	105	2·86	87	3·16
		20	300	·91	260	1·56	230	2·08	175	3·18	140	3·82	116	4·22
		40	360	1·09	315	1·89	280	2·52	210	3·82	170	4·62	140	5·09
		60	380	1·15	330	1·98	295	2·68	220	4·00	177	4·83	147	5·35
		130	400	1·21	350	2·10	310	2·79	230	4·18	185	5·05	155	5·64
3	1·047	12	300	·91	260	1·56	232	2·08	175	3·18	140	3·82	116	4·22
		20	400	1·21	350	2·10	310	2·79	232	4·22	185	5·05	155	5·64
		40	480	1·45	420	2·52	373	3·36	280	5·10	225	6·14	187	6·80
		60	503	1·52	440	2·64	391	3·52	295	5·37	235	6·42	196	7·13
		130	530	1·61	462	2·77	411	3·70	310	5·64	248	6·77	206	7·50
2	1·57	12	450	1·37	390	2·34	350	3·15	260	4·73	209	5·71	174	6·33
		20	600	1·82	520	3·12	467	4·20	350	6·37	280	7·64	232	8·44
		40	720	2·18	630	3·78	560	5·04	420	7·64	348	9·50	280	10·20
		60	760	2·30	663	3·98	592	5·33	442	8·05	355	9·70	295	10·72
		130	795	2·40	695	4·17	619	5·57	462	8·40	370	10·10	309	11·23

HORIZONTAL FLOUR MILLS.

Directions for Fixing and Working the Mills.

Fixing.—Fix the mill in the floor, about 12 feet from the driving shaft, letting down the legs of the frame as far as the black line on the frame. The frame-top should then be lined and levelled up so that the line shaft centre will be about 16″ higher than the top of the bottom cross beam of the frame for forward drive and then the frame legs should be fixed rigid in mortar and concrete. The top stone runs anti-clockwise.

Fitting up.—After the frame is fixed and set firmly in the ground, examine the packing gland box and see that the asbestos packing is fit and tight in the lower stone and also lubricate it well. Then put the top stone on and tighten the cone nut on the top of the spindle. Put the sheet steel cover on and then the hopper with feed regulator. Then the mill is ready for working.

Table giving the H. P. required for different capacities.

Diameter of Stones.	Power required.	Speed per minute.	Will grind per hour.	Price complete with Stones. Approx.
Inches.	B. H. P.	Revs.	Lbs.	Rs.
15	2·5	550	175	220
18	3·5	500	225	230
20	4·5	400	350	245
24	6·5	350	450	330
30	8	375	650	410
36	12	250	850	500

Modern Roller Flour Mills.

In modern flour milling, the release of the floury parts from the inside of the wheat is obtained by means of a gradual breaking down of the wheat berry in the roller mills reducing the grain a little. The wheat is not crushed up in the roller mills, but is cracked and broken open, and the flour scraped from the husk or bran.

It is essential, in order to obtain the best results, that the wheat should be thoroughly cleaned and efficiently conditioned before going on to the first break rolls.

The Horse power taken by the modern roller flour mill can be estimated roughly at 15 H. P. per sack.

COTTON MILLS.

GREAVES COTTON AND CO., LTD.

Approximate Estimate for a Factory of 50 Single Roller Gins.

	Rs.
Motive power.—One coupled compound non-condensing steam engine with cylinders 13″ and 22″ diam. × 24″ stroke; capable of developing 137 H. P.; fitted with a Rope flywheel 9′·8″ diam. × 18″ wide on face ..	12,960
One Lancashire steam boiler 24′·0″ long × 6′·6″ diam., suitable for a working pressure of 160 lbs. per square inch ..	10,620
One single cylinder single acting Donkey pump capable of pumping 670 gallons of water per hour	825
Gins.—50 Macarthy's double action single roller cotton gins with self feeder, coupled crank leg straps, bearings, crank-shaft and fitted with fast and loose pulleys ..	21,000
Gearing for driving with necessary line shaft, couplings, pedestals and W. I. split pulleys	5,000
One second motion pulley	550
Total approximate price ..	50,955

GREAVES COTTON AND CO., LTD.

Approximate Estimate for a Factory of 40 Single Roller Gins.

	Rs.
Motive power.—One coupled compound non-condensing steam engine with cylinders 11″ and 19″ diam. × 20″ stroke; capable of developing 102 H. P. flywheel grooved for 8′·4″ Diam. Rope ..	9,720
One Lancashire Boiler 24′·0″ long × 6′·6″ diam. suitable for working pressure of 160 lbs. per square inch ..	10,620
One single cylinder single acting Donkey pump capable of pumping 670 gallons of water per hour	825
Gins.—40 double action Macarthy's single roller cotton gins complete with self feeder, crankshafts, etc.	16,800
Gearing for driving with necessary line shaft, couplings, pedestals and W. I. split pulley	4,000
One second motion pulley of suitable diam.	500
Total approximate price	42,465

(GREAVES COTTON & CO., LTD., ENGINEERS).

Approximate estimate for a factory of 30 Double Roller Gins.

	Rs.
Motive Power.—One coupled compound Non-condensing Steam Engine with cylinder 11″ and 19″ diam. × 20″ stroke capable of developing 102 H. P. Flywheel grooved for 8′·4″ diam. × 14″ wide on face	9,720
One Lancashire Boiler 24′·0″ long × 6′·6″ diameter, suitable for a working pressure of 160 lbs. per square inch ..	10,620
One single cylinder single acting Donkey pump capable of pumping 670 gallons per hour fitted with flywheel	825
30 Double Roller Cotton gins fitted with beater, moving grids and two bare roller shafts.	25,200
Gearing for Driving above complete	3,000
One second motion pulley	500
Total approximate price	49,865

Ginning Factory to contain 50 Single Roller Gins.

(To be driven by cold starting oil Engine).

	Rs.
One cold starting 3 cylinder vertical crude oil Engine of 165 Max. B. H. P. fitted with flywheel and complete with self-starter, foundation bolts exhaust piping, exhaust silencer, fuel oil service tanks and other tools and accessories ..	20,940
50 Double action Macarthy's Single Roller Cotton Gins complete with self-feeder, etc., as before	21,000
Gearing for driving with necessary line shaft, couplings, etc., as before	5,000
One second motion pulley	550
Total price approximate	47,940

Cotton Baling Press.

One Hydraulic Half press by Henry Berry & Co., with 3 rams, each 7½″ diam. cotton box 17′·0″ deep × 4′·0″ long × 16″ broad, capacity 90 cubic feet.

One hydraulic finishing Press by Henry Berry & Co., with two rams, each 21″ diam. × 16″ stroke, working pressure 3 tons per square inch.

One excavator.

	Rs.
One hydraulic pumping engine having 2 cylinders 13″ diam. and 15″ stroke,, coupled to 12, $1\frac{7}{8}''$ × 8″ stroke pumps complete with foundation bolts, nuts, plates, washers, tools, and water piping ..	45,780
One Lancashire boiler 20′ long and 6′ diam. working pressure 125 lbs. per square inch	7,650
One single cylinder single acting donkey pump capable of pumping 400 gals. per hour	675
Steam piping between hydrauilc pumping Engine, Boiler and Donkey pumps	550
One No. 54 Cotton Weighing machine platform, 5′·10″ × 4′·5″, capacity $3\frac{1}{2}$ cwt.	1,100
Approximate Total	55,755

When it is proposd to drive the factory by Oil Engine, allow at least $3\frac{1}{2}$ B. H. P. per gin.

Presses.

The kick -off valve should be adjusted according to the quality of the cotton. For long staple smooth cotton it is best to knock-off the low pressure pumps at one ton per gin. For short staple hard cotton, the low pressure pumps should be knocked off at $\frac{3}{4}$ ton. per gin.

Oil Expellers.

The following should be mentioned when making an enquiry :—

1. Kind of seed to be treated.
2. Capacity per hour.
3. Power available.
4. Short description of local circumstances.

If Refining Plants are required for oils and fats, please give the following particulars :—

1. Gross quantity of oil to be refined, each 24 hours.
2. Kind of oil or fat to be treated.

For Extraction Plants it is important to have the following details :—

1. Kind of seeds or cake.
2. Approximate percentage of oil in the seed or cake before extraction.
3. Quantity of the above material to be treated, each 24 hours.

Table of Oil Expellers.

Pulleys.		R. P. M. Depending on the kind of Seed.	B. H. P.	Heating Trough.		Nett Weight in Cwts.	Capacity per hour of or Linseed in Mds.	Space Required.			Approx. Price.
Diam.	Width.			Diam.	Length.			Length.	Width.	Height.	
1 ft. $9\frac{1}{2}$ ins.	$4\frac{3}{4}$ ins.	200 to 280	7 to 10	10 ins.	8 ft. 4 ins.	76	5	3 ft. 4 ins.	4 ft. 3 ins.	9 ft. 6 ins.	Rs. 6,000 to 8,000

With the modern pressing plant the following extraction with good quality seeds, should be obtained :—

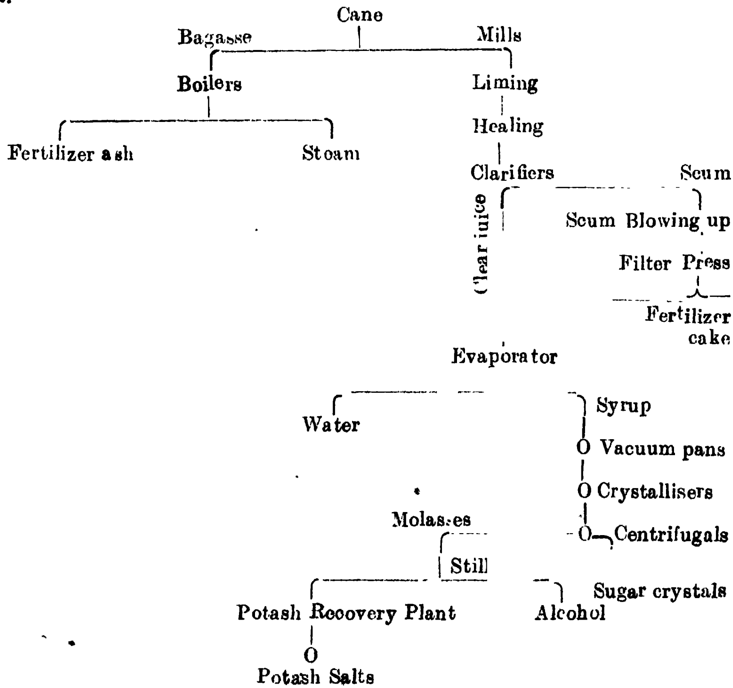
Groundnut	46%
Castor	43%
Copra	41%
Cotton Seed	39%
Rape	34%

With good oil *ghannies* about 15 % less than the above figures are obtained.

SUGAR ROLLER MILLS.

From good sugarcane about 8% to 9% sugar can be extracted and from good gur about 48 % sugar can be extracted.

The diagram below gives a general idea of the process as usually carried out.



For diagram of factory to turn out 5 tons of sugar per 24 hours, see part II page 689.

DISINTEGRATORS.

The principle of disintegrator for lime, ashes, surkhi, etc., is simple. The whole of the grinding being done by four arms or beaters which, revolving at a high speed in an enclosed chamber, strike the material as it is fed in, reducing most of it to powder which instantly passes out through the screens placed in the bottom half of the machine, that which is not sufficiently fine being again struck by the beaters and further reduced. The current of air created keeps the material cool as well as helping it pass out quickly.

Leading Dimensions of Disintegrators.

	Screens used. Inches.	Size of Machine.					
		No. 0	No. 00	No. 1½	No. 2½	No. 3½	No. 4½
Diameter of Beater Chamber		1′-0″	1′-5″	1′-10″	2′-6″	3′-3″	4′-6″
Revs. per minute		5,000	4,000	3300	2000	1700	1300
Approx. B. H. P.		4 to 8	8 to 12	12to18	18 to 27	27 to 45	45 to 75
Diam. of pulley		3″	4″	4″to5″	6″ to 8″	9″ to 11″	12″ to 15″
Width of Belt		3″	3½″	4″	5″	6″	8″
Size of feed inlet hole.		3¼″×2¾″	6″×5″	6″×6″	8½″×6½″	9½×″7½″	12½″×10½″
Prices (Approx.) Rs.		500	650	800	1,250	2,100	3,600
		Approx. capacities per hour in cwts.					
Bones (dry)	$\frac{1}{32}$	..		..	4½	7	..
Brick and tile refuse	$\frac{1}{8}$	..	8	15	25	40	100
Lime	$\frac{1}{16}$	6	10	18	30	55	80
Limestone	$\frac{1}{8}$	..	..	7	14	20	50
Surkhi	$\frac{1}{4}$	..	10	20	35	50	100

ICE MAKING FACTORY.

The two commonest systems of refrigeration are the anhydrous Ammonia (NH_3) and Carbon dioxide (CO_2) systems. The $N. H_3$ system is better owing to the comparatively low pressure at which it can be worked in hot climates. It has a further advantage in that any leakage is at once detected by the smell of the gas.

The CO_2 system is generally employed where the machinery has to be placed in confined spaces, such as on Board ship.

The method of driving whether by belt from electric motor, oil or gas Engines or a compressor directly coupled to a steam Engine should be decided upon first, as the method of driving largely affects the cost of operating the plant.

Two further factors which affect the initial cost are :—(1) The thickness of the ice required to be made.

(2). The usual market demand is for clear or crystal ice, and to obtain this it is either necessary to include a distilling plant to purify the water before freezing, or else to employ some form of agitation by compressed air to the water in the ice cans, while freezing is in process.

The quantity of water necessary for cooling the condenser may be approximately gauged by taking 120 gallons of cooling water per hour for every ton of ice manufactured per day. If the water supply is inadequate the same water may be used over and over again by using some sort of water coolers.

Prices and Particulars.

Ice making Plant capacity per day 24 hours.	15cwt.	1½ton.	3 tons.	6 tons.	10tons.	15tons.	20 tons.
Thickness of Ice made ..	4″	6″	6″	6″	9″	9″	9″
Weight of each Block lbs.	56	112	112	112	225	225	225
B. H. P. ..	4	9	16	27	50	75	100
Prices for Belt driven plant, Approx. Rs. ..	5,000	10,000	15,000	25,000	49,000	70,000	80,000
Prices for Steam driven plant exclusive of Boiler, Rs. ..	..	..	..	30,000	55,000	80,000	100,000

For particular of design, see Part II, page (686) which gives an arrangement of small ice factory driven by oil Engine.

Small Handworked Ice Machine.

It can prepare 2 lbs. of Ice Cream or Raw Ice in 5 minutes and costs about quarter of an anna. The sole mediam used is sulphuric acid 66° Beaume. Ice is produced by chemical action following the absorption of steam. By the turning of a small wheel, the two containers are set in motion, and at the same time the air surrounding the substance to be frozen is withdrawn by means of a vacuum pipe. The resulting chemical process freezes the water when power is available the machine can be geared to it, or can be worked if desired by a small electric or oil motor. The price is approximately Rs. 300.

SODA WATER MACHINERY.

The output of any machine is chiefly regulated by the size of the pumps, and no machine can produce more than the pump can supply, whatever may be the arrangements of condenser, etc.

Approximate Product per working day of 10 hours of full sized bottles at temperature in factory of 50° to 60° Fahr.

Diam. of pump.	Working by hand.	Working by power.	Syrups, drinks in patent bottles, worked by power.
Inches.	Doz.	Doz.	Doz.
Single pump 1¼	100	150	200
,, ,, 1⅜	150	200	300
,, ,, 1¾	250	320	500
,, ,, 2	320	500	750
,, ,, 2½	..	750	1,350
Double pumps 2	600	1,000	1,800
,, ,, 2½	..	1,500	2,500
,, ,, 3	..	2,500	4,000
,, ,, 3½	..	3,200	5,000

Keep the factory cool. A canvas covering over the gas-holder, kept damp while working, may be found useful.

Prices and Particulars.

	Price (Approx.).
Plant of machinery to produce the following per day—	Rs.
80—100 dozens	1,300
150 doz. by hand or 200 doz. by power	1,750
200 doz. by hand or 300 doz. by power, 10 oz. bottles ..	1,600
300 doz. by hand or 400 doz. by power, 10 oz. bottles ..	1,850
320 doz. by hand or 450 doz. by power, 10 oz. bottles ..	2,850
550 doz.	3,000
700 doz.	3,800
1,000 doz.	4,200

WOOD WORKING MACHINERY.

The following list, which gives the various sizes of motors, allows for the motors being capable of giving 25 % over load for not less than 1½ hour,

without any undue heating. The figures are based upon the average work performed in the Workshops.

Machines type and size.	Power of motor required for average works H. P.	REMARKS.
24″ and 30″ Horizontal Log frame saw one blade in use	10	Motor belted to Machine.
36″ ditto	12	ditto.
42″ ditto	15	ditto.
48″ ditto	18 to 20	ditto.
24″ circular saw bench (hand feed). ..	10	ditto.
30″ ditto	12	ditto.
36″ ditto	15	ditto.
42″ ditto	20	ditto.
16″ double dimension saw (hand feed) ..	5	ditto.
18″ diam. cross cut machine ..	3	ditto.
24″ ditto	5	ditto.
30″ ditto	7	ditto.
20″ combined surfacing and thicknessing machine	8	For ordinary seasoned timber surfacing is
24″ ditto	10	hand feed. Thicknessing is power feed.

The above powers assume that the cutters or saws are running at about standard speeds. The power absorbed per square feet surface sawn per minute varies very much in some instances and it is impossible to get anything like the accurate figures.

The following list gives the various speeds, etc., of certain machines.

18″ Circular saw .. 1,800 Revs. per minute.
22″ „ „ .. 1,700
26″ 1,500
32″ 1,250
36″ 1,000
42″ 900

Hand feed bench planning machine which will plane 8″ width 1,000 revolutions per minute.

Hand and Roller feed surface planning, thicknessing and moulding machine.

16″×9″ @ 800 Revs. per minute.
20″×9″ @ 800 Revs. per minute.
24″×9″ @ 800 Revs. per minute.

Vertical Spindle moulding and shaping machine 1000 Revs. per minute.

STEAM ROAD ROLLERS.

For roads metalled with kankar or soft metal or for district roads where soling is often absent or lightly provided, a light 6 ton roller will serve the purpose.

For hard metal 10 to 15 ton roller should be used.

The weight of the roller in working is from 20 to 40 per cent. above its normal weight.

Coal is more suitable as a fuel than wood. If wood fuel is used, the fire-box and fire-bars should be especially adopted for this purpose, and the point should be brought to the notice when ordering a roller.

In a working day of 10 hours, 7 maunds of good coal will be required for a 10 ton compound roller or about 15 to 20 maunds of wood fuel. A Single cylinder roller will use 20 to 30 per cent more.

Compound rollers cost more than single cylinder rollers, but are considerably more economical in fuel and water consumption.

A 10 ton compound roller will require about 300 gallons of water daily and a single cylinder about 20 to 30 per cent. more.

Saline water should be avoided. Boilers should be worked at full pressure. The pressure gauge should be tested periodically.

A roller should not be reversed without shutting off steam. It is dangerous to reverse a roller under steam if it is travelling.

The following stores are needed for a 10 ton compound roller working 10 hours a day :—

1. Good coal 7 maunds or 15 to 20 maunds of wood.
2. Wood fuel for lighting 1 to 2 maunds a week.
3. Cylinder oil 2 pints a day.
4. Heavy engine oil 3 pints a day.
5. Cotton waste, ¾ lb. a day.
6. Grease ½ lb. a day.
7. Kerosine oil, one bottle a week.
8. White or red lead, one lb. of white and ½ lb. of red monthly for joint making.
9. Fine copper wire and worsted 2 or 3 lbs. of each annually for oil cup syphons.
10. Asbestos millboard 4′ × 4′ × $\frac{1}{16}$″, one sheet annually for mud hole and manhole joints, etc.

A 10 ton roller will consolidate about 600 cubic feet of metal in a day.

The following dimension of a 10 and 15 ton roller may be found useful in designing bridges.

Particulars.	10 ton roller.	15 ton rollers.
Diameter of front wheel ..	3′ 9″	3′ 9″
„ „ Hind wheel ..	5′ 3″	5′ 3″
Width of front wheel ..	4′ 0″	4′ 3″
„ of hind wheel ..	1′ 2″	1′ 8″
Load on front wheel ..	5 tons	6 tons
„ „ each hind wheel ..	4 tons	5·5 tons
Distance between hind wheels centre to centre ..	5′ 4″	5′ 4″
Distance between front and hind axles ..	9′ 8″	12′ 0″

MAN AND ANIMAL POWER.

Useful work of men in feet lbs. per minute.

Working for.	8 hours per day.	6 hours per day.
Raising own body	4,250	
Work treadmill	3,900	
Drawing or pushing horizontally	3,120	
,, ,, ,, vertically	2,380	
Turning handle	2,600	
In Rowing	4,000	
Raising material with pulley	..	1,560
,, ,, ,, hands	..	1,470
Carrying material on back returning empty ..	..	1,126

Comparison of Animal Power.

A horse travelling at the rate of 2 miles per hour can exert a continuous pull of 120 lbs. $= \frac{5,280 \times 2 \times 120}{60} = 21,120$ ft. lbs. per minute (working 8 hours a day).

Horse say	..	21,000 ft. lbs. per minute.
Ox	..	12,000 ft. lbs.
Mule	..	10,000 ft. lbs.
Ass	..	3,500 ft. lbs.
Man	..	2,000 ft. lbs.
Engine H. P.	..	33,000 ft. lbs.

Centrifugal Pumps.

The centrifugal pump is essentially an inward flow turbine reversed, the power being applied to rotate the runner and the water being admitted at centre and discharged at the outer periphery.

Let H = head of water in ft.
Q = quantity of water lifted c. ft. per minute.
S = speed of periphery in ft. per second.

$$D = \text{diam. of fan in ft.} = C\sqrt{\frac{Q}{H}} \quad \text{..................(Unwin)}$$

C = a coefficient varying from ·12 to ·18.

$S = 8\sqrt{H}$ in small fans.

$= 9{\cdot}5\sqrt{H}$ in large fans.

Except under special cases the suction lift should not exceed 20 ft. The best results are obtained by keeping the suction lift below 12 ft. See that all suction pipe joints are tight and that the foot valve does not leak. The pump should be primed before starting.

In centrifugal pumps discharge in cusecs $\frac{d^2}{18}$

Where d = diameter of pipe in inches.

PUMPS.

Suction Limits.—Theoretically a pump will lift water about 34 ft. at freezing point but the amount decreases rapidly with rise in temperature until at boiling point no suction lift is possible. Under average Indian conditions, the maximum theoretical suction lift is about 30 ft. In practice, even with moderately cold water 25 to 26 ft. is considered the limit, but from the point of view of efficiency, it is preferable to reduce this as much as possible.

In the case of centrifugal and other high speed pumps, the best results are obtained with a suction lift of 15 ft. or less.

APPROXIMATE QUANTITIES OF WATER DELIVERED PER HOUR BY SINGLE ACTING PUMPS.

Worked at 30 *strokes per minute.*

BORE OF WORKING BARRELS	2 ins.	2¼ ins.	2½ ins.	3 ins.	3½ ins.	4 ins.	4½ ins.	5 ins.	6 ins.
Galls. delivered by Pumps 4in. stroke	80	100	125	180	245	320	405	500	720
Do. do. do. 6 in. do.	120	150	185	270	365	480	605	750	1,080
Do. do. do. 8 in. do.	160	200	250	360	490	640	810	1,000	1,440
Do. do. do. 10 in. do.	200	250	315	450	610	800	1,010	1,250	1,800
Do. do. do. 12 in. do.	240	300	375	540	735	960	1,215	1,500	2,160

For single acting Pumps, driven at a speed of 30 feet per minute, the diameter is equal to the square root of the number of gallons required per minute.—Example required to know the diameter of pump to deliver 36 gallons per minute. The square root of 36 is 6, which is the required diameter of pump.

If pump be worked at 40 strokes per minute, the quantity delivered will be of course one-third more than that given in the table ; if at twenty strokes only, one-third less water will be delivered and so on.

For double acting pumps, the quantities of water delivered, will be precisely double those given for single acting pump if worked, at the same speed and the same length of stroke.

Table giving the loss of head due to friction for every 100 ft. length of pipe.

Galls. per min.	Diameter of Pipe in inches.											
	2	3	4	5	6	7	8	9	10	12	14	16
5	·108											
10	·433	·051										
15	·975	·116										
20	1·73	·206	·045									
30	3·89	·463	·103	·032								
40	6·92	·824	·183	·056								
50	10·8	1·28	·288	·088	·034							
60	15·5	1·86	·410	·127	·049							
70	21·1	2·52	·560	·173	·069	·030						
80	27·5	3·30	·732	·227	·087	·039						
90	35·0	4·11	·927	·286	·109	·049	·024					
100	43·3	5·15	1·14	·355	·136	·061	·030					
120	62·2	7·22	1·65	·505	·195	·088	·043	·023				
140	84·5	10·1	2·27	·700	·288	·119	·055	·032				
160	..	13·2	2·94	·912	·347	·156	·077	·042	·024			
180	..	16·8	3·69	1·15	·443	·197	·097	·054	·033			
200	..	20·6	4·57	1·42	·545	·244	·121	·065	·037			
250	..	32·4	7·20	2·23	·855	·381	·188	·101	·058	·022		
300	..	46·3	10·3	3·20	1·22	·548	·271	·146	·084	·032		
350	..	63·3	14·0	4·35	1·66	·747	·368	·198	·115	·044		
400	..	82·4	18·3	5·67	2·18	·976	·473	·260	·150	·057	·027	
450	..	..	23·1	7·17	2·77	1·23	·611	·328	·189	·073	·035	
500	..	..	28·8	8·86	3·41	1·52	·755	·406	·233	·091	·043	·020
600	..	..	41·0	12·7	4·91	2·14	1.08	·584	·336	·129	·063	·028
700	..	..	56·0	17·3	6·90	3.00	1·47	·797	·458	·176	·085	·039
800	..	..	73·2	22·7	8·70	3·91	1·93	1·04	·600	·231	·112	·051
900	..	..	92·7	28·6	10·9	4·95	2·44	1·31	·757	·292	·140	·065
1000	..	..	..	35·5	13·6	0·10	3·01	1·62	·039	·360	·173	·080

HAND PUMPS.

It should be borne in mind that the force, necessary to work a pump, increases in proportion to the quantity of water lifted per hour and also in proportion to the total height through which the water is lifted.

The following figures will serve as a practical guide :—

ONE MAN CAN PUMP—

3,000 gallons per hour on a lift of 3 feet.	900 gallons per hour on a lift of 10 ft.
1,800 ,, ,, ,, ,, ,, ,, ,, 5 ,,	600 ,, ,, ,, ,, ,, ,, ,, 15 ,,
1,300 ,, ,, ,, ,, ,, ,, ,, 7 ,,	450 ,, ,, ,, ,, ,, ,, ,, 20 ,,

It will be noted that the quantity of water gets less as the height it is raised incareases. For any particular lift the quantity of water which can be raised hand power can be estimated thus:—

$$\frac{9{,}000 \times N}{H}$$

where H is the total height the water is raised in feet and N the number of men who will work the pump together.

Suction Lift.—It is always advisable to arrange for as short a suction lift as possible. The maximum practicable suction lifts may be taken as 25 feet but for ordinary pumps 20 feet and for some types 15 feet should be taken as the limit. It should be understood that the suction lift should always be included in the total height the water is raised.

Hand Rotary Force Pump for Domestic use.

No.	Capacity per minute 50 Revolutions.	Diameter of Suction.	Diameter of Discharge.	Lift and Force.	Approx. Price.	Foot Valves. Each.
	Galls.	Ins.	Ins.	Feet.	Rs.	Rs.
2	6	1¼	1	30	115	7
3	8	1½	1¼	18	125	8
4	13	1½	1½	11	225	8
5	18	2	2	8	260	9

This type of pump should not be more than 15 feet above level of water to be pumped—preferably less.

HOUSE FORCE PUMP.

This is well suited for tube wells. May be used for raising water from 50 to 75 ft. height.

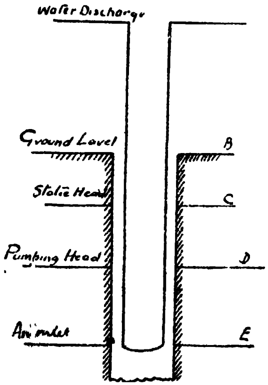
Size No.	Cylinder.	Suction Diameter.	No. of Strokes per Gallon of Water.	Price. Approx.	Foot Valves Each.
	Ins.	Ins.		Rs.	Rs.
2	2½	1¼	10	52	7
4	3	1¼	8	65	7
6	3½	1½	4	95	8
8	4½	2	3	105	9

THE AIR LIFT SYSTEM.

Theory of the Air Lift:—

The theory of the air lift and the reason for submergence are that by mixing the water with air in the discharge, the water is made lighter, so that the pressure of the column of air and water in the bottom of eduction pipe is less per sq. inch than that of the solid water outside, in the well, so that an upward flow is thus created.

Ordinary Air Lift terms:—



1. *Static Head*:—Normal water level when not pumping. Distance "B" to "C."

2. *Drop*—The distance the water recedes when pumping at the desire rate. Distance "C" to "D".

3. *Lift.*—Consists of the Static head plus the drop, plus the elevation. Distance "A" to "D".

4. *Elevation.*—The distance above the ground surface, at the well to which it is necessary to deliver the water. Distance "A" to "B".

5. *Submergence.*—Distance below the pumping head at which the air picks up the water The percentage of submergence means the percentage of the total vertical air lift column, distance "A" to "E" which is submerged in the solid liquid column in the well, when pumping, distance D to E. Starting submergence, distance "C" to "E", and working submergence distance "D" to "E".

Starting Pressure = Starting submergence × ·434 lbs.

working pressure = (working submergence × ·434) + Friction in air pipe line.

Advantages of the Air Lift.—

(*a*) The whole of the machinery is situated in one convenient central station thus allowing a ready constant access to an Engineer, assuring continuous and satisfactory performance.

(*b*) The plant is not affected by constant shut downs.

(*c*) More water will be obtained from any given well with air lift than can be pumped by any other means.

(*d*) By periodical back blowing, the strainer is kept clean, the sand is washed out thereby increasing the yield of well. Back blowing is effected by closing the discharge pipe and increasing the compressive pressure whereby the air blows through the holes of the strainer, to effect back blowing the top of the tube must be air tight.

(*e*) A change in pumping level has little effect on efficiency.

(*f*) Character of water is improved as to purity and solubility, due to aeration.

The correct strainer for wells of this class, is a perforated screen with openings of a suitable size to admit the fine material into the well, from which it can be pumped, and to hold back the coarser particles, so as to form a natural gravel filter bed outside of the original strainers.

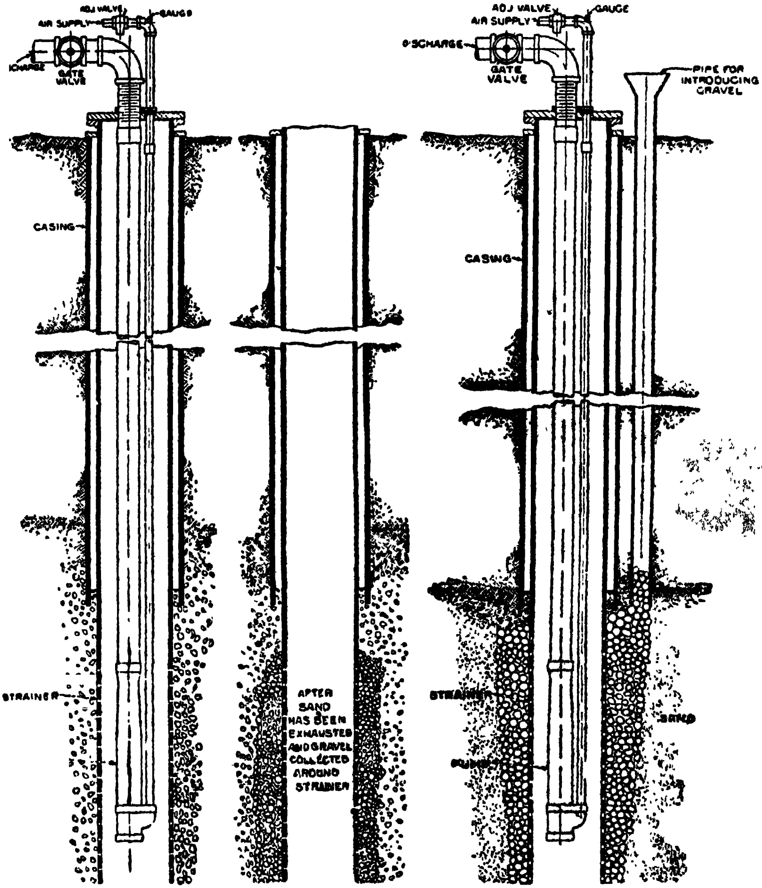


Fig 1 Fig 2 Fig 3

Sketches to show construction of wells in sand and gravel formation

Any number of wells may be pumped from one central station. One air compressor may handle a number of wells.

Equipment Required :—

(1) Air compressor ; (2) Air Receiver.
(3) Pipe lines ; (4) Pump or foot-piece made of Bronze.
(5) Head piece ; (6) Well cap (A casting closing the top of the well, forming a support for the piping and back blowing to keep the strainer clear.)

Ratio of lift to submergence :—

For lift up to 50 ft. ..70 to 66% submergence.
50 to 100 ft. ..66 to 55%
100 to 200 ft. ..55 to 50%
200 to 300 ft. ..50 to 43%
300 to 400 ft. ..43 to 40%
400 to 500 ft. and onward ..40 to 33%

The following should be observed when making an accurate estimate for an air lift Installation :—

1. Number of wells. Say whether one or more wells are to be installed.
2. Accurate depth in feet should be stated.
3. Mention the depth to which the well is cased and say whether it is air-tight.
4. Mention the diameter of well in inches and character of casing.
5. Reduction. Say how much and at what point a well is reduced.
6. Mention the character of strata and the depth to water strata.
7. Kind of strainer used.
8. Static head.
9. Gallons of water to be pumped per minute.
10. Show by sketch the actual distance of pipes. Complete information is important.

Air Lift Table.

$$V = \frac{L}{C. \log. \frac{H+34}{34}}$$

Where V = volume of free air required to raise one gallon of water per minute.
L = Total lift in ft.
H = Running submergence in ft.
C = Constant.

TABLE OF CONSTANTS.

Submergence ..	75%	70%	65%	60%	55%	50%	40%	33%
Value of constant ..	305	298	290	280	264	246	205	180

Ratio of Submergence to Lift.

Working pressure = (*submergence in ft.* × ·434) + 5.

Lift in ft.	33% ½—1 Free air in c. ft.	33% ½—1 Working pressure.	43% ¾—1 Free air in c. ft.	43% ¾—1 Working pressure.	50% 1—1 Free air in c. ft.	50% 1—1 Working pressure.	55% 1¼—1 Free air in c. ft.	55% 1¼—1 Working pressure.	60% 1½—1 Free air in c. ft.	60% 1½—1 Working pressure.	66% 2—1 Free air in c. ft.	66% 2—1 Working pressure.	70% 2⅓—1 Free air in c. ft.	70% 2⅓—1 Working pressure.	Remarks.
20	..	..	..	..	·40	14	·30	16	·26	18	·20	23	·18	26	
30	..	..	..	..	·45	18	·34	22	·29	25	·23	31	·19	37	
40	..	..	..	..	·48	22	·36	26	·32	31	·26	39	·22	48	
50	..	..	..	..	·53	27	·40	32	·35	38	·29	49	·25	53	
60	..	..	..	..	·56	31	·45	38	·38	44	·32	57	·27	69	
80	..	..	..	..	·62	40	·51	50	·43	58	·36	75	·32	90	
100	..	..	·90	38	·69	49	·57	59	·48	71	·41	93	·36	106	
120	..	..	·97	44	·75	57	·62	70	·53	83	·46	109	·41	126	
140	..	..	1·05	51	·81	66	·68	81	·57	96	·50	127	·45	152	
160	..	..	1·12	57	·87	74	·73	92	·62	109	·54	143	·49	167	
180	..	..	1·18	63	·92	84	·78	104	·67	123	·58	163	·53	188	
200	1·87	49	1·25	70	·98	94	·82	114	·71	138	·62	183	·57	210	
250	2·08	61	1·41	87	1·10	114	·95	142	·81	168	·72	223	·66	258	
300	2·27	73	1·56	102	1·23	136	1·05	170	·91	201	·81	267	·74	307	
350	2·46	81	1·71	118	1·39	158	1·16	196	1·00	235	·89	311	·82	368	
400	2·66	92	1·85	135	1·47	179	1·27	222	1·10	266	·98	353	·91	410	
450	2·84	102	2·00	152	1·59	202	1·38	250	1·19	300	1·07	399	1·00	515	
500	3·01	113	2·20	166	1·71	222	1·49	275	1·29	330	1·15	439	1·06	..	
600	3·35	135	2·40	202	1·93	265	1·72	330	1·46	395	1·31	527	..	..	
700	3·69	158	2·62	235	2·17	309	1·93	386	1·65	461	1·47	613	..	..	
800	4·04	178	2·88	265	2·36	352	2·05	439	1·80	525	1·65	699	..	..	
900	4·34	200	3·12	300	2·56	396	2·23	495	1·92	591	1·77	787	..	..	
1,000	4·63	228	3·35	330	2·97	439	2·41	548	2·12	656	1·93	873	..	..	

Horse-power (Theoretical) required to compress 100 *c. ft. of free air to various pressures.*

(Sullivan Machinery Company).

Gauge Pressure.	Single Stage.	Two Stage.	Saving of two stage over single stage compression.	
			H. P.	Per cent.
5	1·97			
10	3·61			
15	5·02			
20	6·28			
25	7·44			
30	8·45			
35	9·41			
40	10·30			
45	11·13			
50	11·92	10·65	1·28	10·70
60	12·67	11·81	1·57	11·72
70	14·70	12·84	1·85	12·61
80	15·91	13·77	2·13	13·40
90	17·04	14·63	2·41	14·22
100	18·09	15·42	2·67	14·77
120	20·01	16·83	3·18	15·90
140	21·74	18·07	3·67	16·89
160	23·32	19·26	4·06	17·40
180	24·77	20·27	4·51	18·18
200	26·12	21·19	4·93	18·88
220		21·96		
240		22·76		
260		23·28		
280		24·19		
300		24·85		
350		26·35		
400		27·65		
450		28·85		
500		29·97		

Loss of Air Pressure in pipes, due to friction (applies to all pressures and for volumes up to 300 *c. ft. of free air).*

(*Sullivan Machinery Company.*

C. ft. of free air per minute.	Divide the number corresponding to the diameter of the pipe and volume in c. ft. of free air by the ratio of compression from free air. The result is the loss in lbs. per sq. inch in 1,000 ft. of pipe. DIAMETER OF PIPE IN INCHES.							
	½	¾	1	1¼	1½	2	2½	3	3½
6	43·5	5·7	1·4	·4					
12	173	22·8	5·3	1·5					
24	753	91·0	21·0	5·9	2·2				
48		362·0	85·0	23·5	8·5	2·0			
75			200·	57·0	21·0	4·9	1·6		
100			373·	92·0	37·5	8·7	2·7		
125				163·0	59·0	13·6	4·4		
150				230·0	83·5	19·5	6·3	2·3	
200				368·0	150·	35·0	10·8	3·7	
250					216	54·5	17·7	6·4	2·9
300					338·	79·0	25·3	9·3	4·2
	2	2½	3	3½	4	4½	5	6	7
350	105	33	12·7	5·5	2·7				
400	140	45	14·8	7·1	3·6	1·9			
450	174	55	20·7	9·4	4·1	2·3			
500	216	68	26·0	11·1	5·6	2·9	1·7		
600	316	100	37·0	16·6	7·3	4·0	2·5		
700		133	51·0	21·8	10·9	5·8	3·4		
800		172	59·0	29·0	14·3	7·5	4·4	1·8	
900		219	83·0	38·0	16·5	9·2	5·4	2·2	
1000		272	104·0	44·0	22·0	11·7	6·8	2·8	1·4
1200		400	148·0	67·0	29·0	16·0	9·6	3·9	1·9
1400			204·0	87·0	44·0	23·0	14·0	5·5	2·6
1600			236·0	114·0	57·0	30·0	18·0	7·1	3·1
1800			332·0	150·	66·0	35·0	22·0	8·8	4·3
2100				196·	98·0	52·0	30·0	12·5	5·9
2400				266·	117·0	65·0	38·0	15·5	7·7
2700					149·0	82·0	49·0	19·5	9·8
3000					201·0	100·0	60·0	24·0	12·0

Example.—What is the loss of pressure and the terminal pressure with 350 c. ft. of free air compressed to 90 lbs? Initial gauge pressure passing through 500 ft. of 2 inch pipe.

From the table we find that the number corresponding to the diameter of pipe and the volume mentioned is 105.

$$\frac{90+14\cdot7}{14\cdot7} = 7\cdot1 \text{ compressions}, \quad \frac{1000}{500}=2, \quad \frac{105}{2}., \quad \frac{52\cdot5}{7\cdot1} \quad 7\cdot4 \text{ lbs. loss.}$$

∴ Terminal pressure 90—7·4 =82·6 lbs.

Loss of Head of Water in Pipes by friction.—For air lift computations friction head, in ft., for each 100 ft. of pipe, for clean iron pipe of the size shown, discharging given volumes in gallons per minute.

Gallons per minutes.	Loss of head due to friction, in ft. and pipe, in inches.														
	¾″	1″	1¼″	1½″	2″	2½″	3″	3½″	4″	5″	6″	7″	8″	9″	10″
5	7·59	1·93	·71	·27	·092	·046	..	..	..	..	..	..	..	..	..
10	29·90	10·26	2·41	1·08	·277	·092	·046	..	..	..	..	..	..	..	..
15	66·01	16·05	5·47	2·23	·577	·138	·092	·046	..	..	..	..	..	..	..
20	115·92	28·29	9·36	3·81	·970	·323	·138	·069	..	..	..	..	..	..	..
25	180·0	43·70	14·72	5·02	1·43	·485	·231	·092	..	..	..	..	..	..	..
30	..	63·25	21·04	8·62	2·09	·693	·300	·138	..	..	..	..	..	..	..
35	..	85·10	28·52	11·61	2·76	·92	·393	·208	..	..	..	..	..	..	..
40	..	110·40	37·03	14·99	3·68	1·19	·530	·254	..	..	..	..	..	..	..
50	..	..	57·27	23·00	5·61	1·86	·80	·393	·138	..	..	..	..	..	..
60	..	..	85·50	32·95	8·88	2·70	1·155	·555	·208	..	..	..	..	..	..
70	..	..	11·400	44·60	11·09	3·46	1·385	·879	·30	·116	..	..	..	..	..
80	..	..	..	58·45	14·55	4·62	2·08	·948	·44	·162	..	..	..	..	..
90	..	..	..	81·50	18·02	5·96	2·54	1·247	·581	·185	..	..	..	..	..
100	..	..	..	89·70	21·75	7·36	3·01	1·478	·60	·208	..	..	..	..	..
150	..	..	..	..	48·76	16·10	6·55	3·12	·76	2·77	·115	..	..	..	..
200	..	..	..	..	..	28·68	11·54	5·50	1·59	·578	·231	·092	..	..	..
250	..	..	..	..	..	..	17·84	8·55	2·82	·972	·393	·162	..	..	..
300	..	..	..	..	..	..	25·7	11·63	4·37	1·504	·601	·277	·162	..	..
350	..	..	..	..	..	..	..	16·40	6·15	2·15	·85	·393	·208	·115	..
400	..	..	..	..	..	..	..	21·36	8·44	2·91	1·15	·531	·277	·161	..
450	..	..	..	..	..	..	..	..	10·92	3·72	1·50	·693	·37	·208	..
500	..	..	..	..	..	..	..	..	13·88	4·62	1·87	·855	·462	·254	·161
750	..	..	..	..	..	..	..	..	17·16	5·55	2·22	1·04	·578	·32	·204
1000	..	..	..	..	..	..	..	..	..	11·28	5·11	2·34	1·22	·694	·416
1,500	..	..	..	..	..	..	..	..	..	..	8·98	4·16	2·17	1·22	·74
2,000	..	..	..	..	..	..	..	..	..	..	..	9·45	4·84	2·704	1·618
										..	..	..	8·70	..	2·84

ficiencies of Air Compressors at Different Altitudes.

Altitude Feet.	Barometric Pressure. Inches. Mercury.	Barometric Pressure. Pounds per Square Inch.	Volumetric Efficiency Compressor Per Cent.	Loss of Capacity Per Cent.	Decreased Power Required Per Cent.
0	30·00	14·75	100	0	0
1,000	28·88	14·20	97	3	1·8
2,000	27·80	13·67	93	7	3·5
3,000	26·76	13·16	90	10	5·2
4,000	25·76	12·67	87	13	6·9
5,000	24·79	12·20	84	16	8·5
6,000	23·86	11·73	81	19	10·1
7,000	22·97	11·30	78	22	11·6
8,000	22·11	10·87	76	24	13·1
9,000	21·29	10·46	73	27	14·6
10,000	20·49	10·07	70	30	16·1
11,000	19·72	9·70	68	32	17·6
12,000	18·98	9·34	65	35	19·1
13,000	18·27	8·98	63	37	20·6
14,000	17·59	8·65	60	40	22·1
15,000	16·93	8·32	58	42	23·5

APPROXIMATEC COST OF AIR LIFT PUMPING PLANT.

Details :—

No. of wells	..	1
Depth	ft.	300
Diam. casing	Inches.	8"
Depth of casing	ft.	180
Strainer	,,	180—300
Inside Drain strainer	Inches.	6
Static Level	ft.	25
Drop	,,	10
Elevations	,,	45
Horizontal Discharge Max.	,,	10
Total Lift	,,	80
Submergence	,,	140
Depth of pump in well	,,	175
Volume of air per gallon	c. ft.	·439
Water pressure	lbs.	56·76
Friction	,,	1·5
Operating pressure	,,	58·25
Gallons per minute required	,,	200
Total air	c. ft.	88
Water H. P.	,,	4·85
B. H. P.	,,	16·1
Over all efficiency	,,	30%

Details of Cost :—

		Rs.
1	single stago double acting Air Compressor, belt driven complete	2,000
1	Vertical Air Receiver, $22\frac{1}{2}''$ dia. 5′ high, complete with pressure gauge, etc.	400
1	Air Lift Pump with $3\frac{1}{2}''$ eduction pipe $1\frac{1}{2}''$ air line, complete with well head, nipple, regulating cock, jam nut and elbow..	925
1	Portable Steam Engine with cylinder, $8\frac{1}{2}''$ dia. and 12″ stroke, with flywheel 54″ dia. × 6′ face for working pressure of 120 lb. per sq. inch to run at 155 Rev. P. M. and 21 H. P...	4,800
	Pipes and Fittings	650
	Approx. total cost	8,775
	Freight, etc.	225
	Total ..	9,000

Air Lift Pumps Standard TYPE (*Sullivan*).

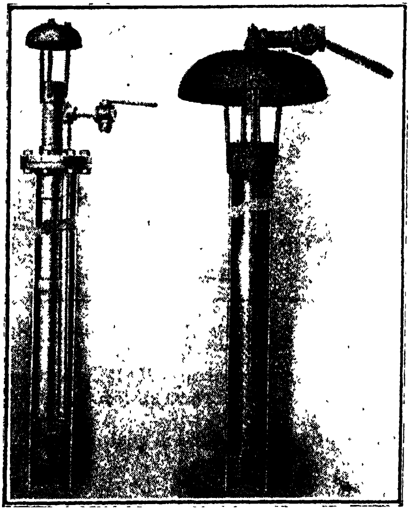
Nominal Pump and Size Dis. Ins.	Approx. Capacity Galls. per Minute.	Smallest Well Casing adapted. Ins.	Approx. Price.			
			Foot Piece.	Well Top.	Umbrella or Elbow.	Complete Pump.
			Rs.	Rs.	Rs.	Rs.
$1\frac{1}{2}$	16	4	400	135	60	537
2	40	5	530	175	75	705
$2\frac{1}{2}$	60	6	635	175	75	835
3	80—120	6	665	225	100	890
$3\frac{1}{2}$	120—160	8	725	250	125	975
4	160—240	8	785	275	125	1,060
$4\frac{1}{2}$	240—280	8	855	300	175	1,155
5	280—400	10	915	325	175	1,240
6	400—600	12	1,055	350	250	1,405
7	600—800	14	1,290	375	250	1,665
8	800—1000	14	2,450	425	250	2,875
10	1000—1600	..	2,840	535	375	3,375
12	1600—2400	..	3,225	650	375	3,875

Central Type Sullivan Air Lift Pump.

Discharge Ins. and Pump No.	Approx. Capacity Galls. per Minute.	Smallest Well Casing adapted. Ins.	Approx. Price.			
			Foot Piece.	Well Top.	Umbrella "Y" Bend.	Complete Pump.
			Rs.	Rs.	Rs.	Rs.
1½	12—24	3	140	135	60	275
2	24—40	3	190	175	75	365
2½	40—56	4	200	200	75	400
3	56—80	4	275	225	100	500
3½	80—120	5	335	250	125	585
4	120—160	6	375	275	125	650
4½	160—200	6	425	300	165	725
5	200—240	7	475	325	165	800

Larger sizes made up to 2,600 gallons per minute.

Sullivan Standard Foot Piece and Well Top, showing relative location of casing and flanges.



Sullivan Central Foot Piece and Umbrella.

The central type is used when more water is required. It is also made of bronze and consists of perforated tube. It has a large number of holes and can be raised or lowered without changing the discharge pipe.

Pumping by Wind-mill.

H. P. of Wind-mill = ·00000091 AV^3 (Molesworth).
Where A = total area of sails in sq. ft.

V = velocity of wind, ft. per second.

The lowest force that will do effective work with a wind-mill is 8 miles per hour. For pumping water for storage for all uses there is no more economical prime mover.

The following table gives the sizes of wind-mills in common use, their power and capacity for pumping water with an average of 16 miles wind for 8 hours per day :—

Diameter of mill.	H. P. from shaft.	H. P. in water pumped.	Gallons of water 15 ft. high per hour.	Gallons of water 25 ft. high per hour.
8½	·09	·04	616	370
10	·16	·12	1918	1151
12	·25	·21	3420	2036
14	·40	·28	4530	2708
16	·50	·41	6460	3876
18	·70	·61	9768	5861
20	1·0	·79	12465	7479
25	1·50	1·34	21233	12743
30	3·0	2·25	31660	19000 (Hiscox).

Wind-mill for Electric Lighting.

A wind-mill 30 ft. in diam. equal to 3 H. P. in a 16-mile wind, running a dynamo will generate current for 25, incandescent lights of 16 candle power each.

For supplying current when the wind is light or during a calm, use storage battery.

ELECTRICAL ENGINEERING.

Direct current.

Electrical Units :—

The *Ampere* is the unit of electrical current $= C = 10^{-1}$

The *volt* is the unit of electro-motive force $= E = 10^{8}$

The *Ohm* is the unit of Resistance $= R = 10^{9}$

Ohm's Law $C = \frac{E}{R}$ (Direct current).

$C = \frac{E}{Z}$ (Alternating currents).

Impedance (Z) is the total resistance of an alternating current circuit, and is expressed in Ohms.

The *Watt* is the unit of power $= 10^{7}$ ergs per second $\text{Watts} = C \times E = C^{2}R = \frac{E^{2}}{R}$.

1 Horse power = 746 Watts.

The " Force de Cheval " = 736 Watts and is the value of H. P. adopted in France, Germany, etc.

Board of Trade Unit.—For commercial purposes electrical energy is charged for in units of 1000 Watt hour each and is known as B. O. T. unit.

1. B. O. T. Unit = $1\frac{1}{3}$ H. P. per hour or H. P. Hours. One B. O. T. Unit will maintain one 16. C. P. 25 Watt lamp for 40 hours, or one 32 C. P. 40 Watts for 25 hours.

Commercial Units.

$$\textit{Load Factor} = \frac{\text{No. of units sold} \times 100.}{\text{Max. capacity plant in K. W.} \times \text{hours of supply.}}$$

Example.—A plant generating 1,000,000 B. O. T. units in a year of 8,760 hours and recording a maximum output of 100 K. W. has a Load factor of 11·4.

Diversity factor is the number obtained by dividing the sum of the Max. Loads of the individual consumers supplied by any works during a given period of time by the Max. load, delivered from the works during the same period.

Example.—Thus if 10 houses take 8 K. W. and if the supply never exceeds 50 K. W., the Diversity factor $= \frac{80}{50} = 1{\cdot}6$.

Resistance and Temperature.

For practical purposes the variation of Resistance with change of temperature is calculated as follows:—

$$R = R^{\circ}\ (1 + KT).$$

Where R = Resistance at temperature T°.
R° = Resistance at temperature 0°.
K = constant depending upon the quality of metal in the wire.
T = temperature in degrees.

K has the following values for different metals:—

Phospher bronze	·000743	Iron	·00472
Silicium-Bronze	·000740	Copper	·00402

Example.—The resistance of Copper wire at 0°. temperature is ·00000 16 Ohm., find its resistance at 50°.

$$R = R^{\circ}\ (1 + KT) = \cdot 0000016\ (1 + 50 \times .00402).$$
$$= \cdot 000001922 \text{ Ohm's.}$$

Accumulators.—Apparatus for chemically restoring electrical energy.

Alternating current.—Current flowing to and fro many times per second and reversing its direction from positive to negative and used chiefly for transmission of power at high pressures.

Ammeter.—An instrument used for measuring current passing through a conductor.

Armature.—The portion of a Dynamo in which the electric current are induced.

Commutator.—Bars of Copper which form the ends of the armature coils and from which the current is collected through brushes.

Rheostat.—An instrument consisting of one or more resistance coils for varying the resistance of anelectric circuit.

Series wiring.—A system of wiring in which the same current travels through two or more lamps before completing its circuit.

Short Circuit.—An accidental connection between the positive and negative conductors by which the current may take a short cut instead of completing its full circuit through the lamp, motor, &c., etc.

Switch.—A device for completing or breaking an electric circuit.

Transformer.—An instrument for reducing or transforming a high pressure to a low one by induction.

Temperature coefficients and specific resistance of pure metals and Alloys.

PURE METALS. (Fleming and Dewar.)	SPECIFIC RESISTANCE PER CUBIC C.M. AT 0° C. In Micr. Ohms.	Mean Temperature Coefficient between 0° and 100° C.
Silver	1·468	0·00400
Copper	1·561	0·00428
Gold	2·197	0·00377
Aluminium	2·665	0·00435
Magnesium	4·355	0·00381
Zinc	5·751	0·00406
Nickel (electrolytic)	6·935	0·00618
Iron	9·065	0·00625
Cadmium	10·023	0·00419
Palladium	10·219	0·00354
Platinum (annealed)	10·917	0·003669
Tin (pressed)	13·048	0·00440
Thallium (pressed)	17·633	0·00398
Lead (pressed)	20·380	0·00411
Bismuth (electrolytic)	110·000	0·00433
Mercury (pure)	94·070	0·00098

ALLOYS. (Fleming and Dewar.)	Micr. ohms.	Temp. Coeff. at 15° C.	Composition in per cent.
Platinum-Silver	31·582	0·000243	Pt. 33% ; Ag 66%
Platinum-Iridium	30·896	0·000822	Pt. 80 : Ir. 20
Platinum-Rhodium	21·142	0·00143	Pt. 90 ; Rh. 10
Gold-Silver	6·280	0·00124	Au 90 ; Ag. 10
Manganese-Steel	67·148	0·00127	Mn. 12 ; Fe 80
Nickel-Steel	29·452	0·00201	Ni 435
German-Silver	29·982	0·000273	Cu_5 ; Zn_3 ; Ni 2
Brass	7·2	..	....
Manganin	46·678	0·0	Cu 84 ; Mn 12 ; Ni 4
Aluminium-Silver	4·641	0·00238	Al 94 ; Ag 6
Aluminium-Copper	2·904	0·00381	Al 94 ; Cu 6
Copper-Aluminium	8·847	0·000897	Cu 97 ; A 13
Copper-Nickel Aluminium	14·912	0·000645	Cu 87 ; Ni 6·7 ; Al 6·5
Titanium-Aluminium	3·887	0·00290	....

Particulars of Copper wires S. W. G

STANDARD WIRE GAUGE.			Amperes at 1,000 per sq. in., loss=2½ volts per 100 yards.	Amperes at I. E. E. standard current =2·6 (area)·82	WEIGHT.		RESISTANCE.	
S.W.G.	Diam.	Area= $d^2 \times \cdot 7854$			lb. per yard.	lb. per mile.	Ohms. per yard.	Ohms. per mile.
1 Sq. inch.	Inches	1 Sq. inch.	1000·	749·9	11·56	20350·	·00002405	04232
7/0	·500	·1963	196·3	197·3	2·270	3995·	·0001225	·2156
6/0	·464	·1691	169·1	174·6	1·955	3441·	·0001422	·2503
5/0	·432	·1466	146·6	155·3	1·695	2983·	·0001640	·2887
4/0	·400	·1257	125·7	136·9	1·453	2558·	·0001913	·3367
3/0	·372	·1087	108·7	121·5	1·257	2212·	·0002212	·3893
2/0	·348	·09511	95·11	108·9	1·100	1935·	·0002528	·4450
1/0	·324	·08245	82·45	96·90	·9534	1678·	·0002917	·5133
1	·300	·07069	70·69	85·41	·8176	1439·	·0003402	·5987
2	·276	·05983	59·83	74·49	·6921	1218·	·0004019	·7073
3	·252	·04988	49·88	64·17	·5767	1015·	·0004821	·8484
4	·232	·04227	42·27	56·02	·4888	860·2	·0005688	1·001
5	·212	·03530	35·30	48·33	·4082	718·4	·0006810	1·199
6	·192	·02895	28·95	41·07	·3347	589·1	·0008307	1·462
7	·176	·02433	24·33	35·61	·2813	495·1	·0009881	1·739
8	·160	·02011	20·11	30·46	·2325	409·2	·001195	2·104
9	·144	·01629	16·29	25·63	·1884	331·5	·001476	2·598
10	·128	·01287	12·87	21·13	·1488	261·9	·001868	3·288
11	·116	·01057	10·57	17·98	·1222	215·1	·002275	4·004
12	·104	·008495	8·495	15·03	·09824	172·9	·002831	4·982
13	0·92	·006648	6·648	12·29	·07688	135·3	·003617	6·366
14	·080	·005027	5·027	9·775	·05813	102·3	·004784	8·419
15	·072	·004072	4·072	8·223	·04709	82·87	·005904	10·39
16	·064	·003217	3·217	6·779	·03720	65·47	·007478	13·16
17	·056	·002463	2·463	5·445	·02848	50·12	·009762	17·18
18	·048	·001810	1·810	4·230	·02093	36·83	·01328	23·38
19	·040	·001257	1·257	3·137	·01453	25·58	·01913	33·67
20	·036	·0010182	1·018	2·638	·0177	20·72	·02362	41·57

Particulars of Copper wires S. W. G. (concld.).

STANDARD WIRE GAUGE.			Amperes at 1000 per sq. in., loss=2½ volts per 100 yards.	Amperes at I.E.E. standard current =2·6 (area)·82.	WEIGHT.		RESISTANCE.	
S.W.G.	Diam.	Area= d² × ·7854.			lb. per yard.	lb. per mile.	Ohms. per yard.	Ohms. per mile.
21	·032	·0008048	·8042	2·142	·009301	16·37	·02990	52·62
22	·028	·0006154	·6158	1·747	·007120	12·53	·03905	68·72
23	·024	·0004521	·4524	..	·005231	9·206	·05316	93·55
24	·022	·0003802	·3801	..	·004395	7·735	·06324	111·3
25	·020	·0003145	·3142	..	·003633	6·394	·07654	134·7
26	·018	·0002542	·2545	..	·002943	5·179	·09449	166·3
27	·0164	·000211	·2112	..	·002442	4·298	·1139	200·4
28	·0148	·0001720	·1720	..	·001989	3·500	·1398	246·0
29	·0136	·0001453	·1453	..	·001680	2·957	·1655	291 3
30	·0124	·0001208	·1208	..	·001397	2·458	·1990	350·3
31	·0116	·0001057	·1057	..	·001222	2·151	·2275	400·4
32	·0108	·00009161	·9161	..	·001059	1·864	·2625	462·0
33	·0100	·00007854	·07854	..	·0009080	1·598	·3061	538·8
34	·0092	·00006648	·06648	..	·0007688	1·353	·3617	636·6
35	·0084	·00005542	·05542	..	·0006409	1·128	·4339	763·6
36	·0076	·00004536	·04536	..	·0005245	·9231	·5301	933·0
37	·0068	·00003632	·03632	..	·0004200	·7391	·6620	1165·
38	·0060	·00002827	·02827	..	·0003269	·5753	·8506	1497·
39	·0052	·00002124	·02124	..	·0002456	·4322	1·132	1992·
40	·0048	·00001810	·01810	..	·0002093	·3683	1·328	2338·
41	·0044	·00001521	·01521	..	·0001759	·3095	1·581	2782·
42	·0040	·00001257	·01257	..	·0001453	·2558	1·913	3367·
43	·0036	·00001018	·01018	..	·0001177	·2072	2·362	4157·
44	·0032	·000008042	·008042	..	·00009301	·1637	2·990	5262·
45	·0028	·000006158	·006158	..	·00007120	·1253	3·905	6872·
46	·0024	000004524	·004524	..	·00005231	·09206	5·316	9355·
47	·0020	·000003141	·003141	..	·00003632	·06392	7·654	13470·
48	·0016	000002011	·002011	..	·00002325	·04092	11·95	21040·
49	·0012	·000001131	·001131	..	·00001308	·02302	21·26	37420·
50	·0010	·0000007854	·0007854	..	·00000908	·01598	30·61	53880·
1Sq. cm.	·4442	·1550	155·0	162·6	1·792	·3154	·0001551	·2730

Details of Conductors. (Electric Light Cables, etc.).

S.W.G.	Diam. of each wire.	Diam. of the strand.	Area.	Resistance at 60° F. per 1000 yards.	Weight per 1000 yards.
	Ins.	Ins.	Sq. in.	Ohms.	lbs.
3/25	0·020	·043	0·00096	25·955	11
3/24	0·022	·047	0·00116	21·454	13·5
3/23	0·024	·052	0·00138	18·026	16
3/22	0·028	·060	0·00188	13·243	22
3/21	0·032	·069	0·00246	10·144	28
3/20	0·036	·078	0·00311	8·0118	36
3/19	0·040	·086	0·00384	6·4899	44
3/18	0·048	·103	0·0055	4·5066	64
7/25	0·020	0·060	0·0022	11·124	25·5
7/24	0·022	0·066	0·0027	9·1952	31·5
7/23	0·024	0·072	0·0032	7·7256	37
7/22	0·028	0·084	0·0043	5·6757	51
7/21½	0·030	0·090	0·0050	4·9445	58
7/21	0·032	0·096	0·0057	4·3460	66
7/20½	0·033	0·099	0·0064	4·0864	75
7/20	0·036	0·108	0·0072	3·4336	84
7/19	0·040	0·120	0·0089	2·7813	104
7/18	0·048	0·144	0·0129	1·9314	149
7/17	0·056	0·168	0·0175	1·4190	203
7/16	0·064	0·192	0·0229	1·0864	266
7/15	0·072	0·216	0·0290	0·8584	336
7/14	0·080	0·240	0·0358	0·6953	415
7/13	0·092	0·276	0·0474	0·5257	549
7/12	0·104	0·312	0·0606	0·4114	701
7/11	0·116	0·348	0·0754	0·3307	872
7/10	0·128	0·384	0·0918	0·2716	1062
7/9	0·144	0·432	0·1162	0·2146	1343
7/8	0·160	0·480	0·1435	0·1752	1660
7/6	0·192	0·576	0·2067	0·1207	2390
19/24	0·022	0·110	0·0073	3·3877	85
19/23	0·024	0·120	0·0087	2·8463	101·5
19/22	0·028	0·140	0·0119	2·0910	138
19/21	0·032	0·160	0·0156	1·6011	180
19/20	0·036	0·180	0·0197	1·2650	228
19/19	0·040	0·200	0·0244	1·0247	282
19/18	0·048	0·240	0·0351	0·7115	406
19/17	0·056	0·280	0·0478	0·5228	553
19/16	0·064	0·320	0·0624	0·4002	722
19/15	0·072	0·360	0·0790	0·3162	914
19/14	0·080	0·400	0·0976	0·2561	1128
19/13	0·092	0·460	0·1290	0·1937	1491
19/12	0·104	0·520	0·1649	0·1515	1906
19/11	0·116	0·580	0·2052	0·1218	2372

Details of Conductors.—(concluded).

S. W. G.	Diam. of each wire.	Diam of the strand.	Area.	Resistance at 60° F. per 1000 yards.	Weight per 1000 yards.
	Ins.	Ins.	Sq. ins.	Ohms.	lbs.
19/10	0·128	0·640	0·2498	0·1000	2888
19/9	0·144	0·720	0·3162	0·07906	3655
19/8	0·160	0·800	0·3904	0·06406	4513
19/7	0·176	0·880	0·4724	0·05292	5461
37/24	0·022	0·154	0·0143	1·7396	165
37/23	0·024	0·168	0·0171	1·4647	198
37/22	0·028	0·196	0·0233	1·0737	270
37/21	0·032	0·224	0·0304	0·8222	352
37/20	0·036	0·252	0·0386	0·6496	446
37/19	0·040	0·280	0·0476	0·5262	550
37/18	0·048	0·336	0·0686	0·3654	793
37/17	0·056	0·392	0·0934	0·2684	1080
37/16	0·064	0·448	0·1220	0·2055	1410
37/15	0·072	0·504	0·1544	0·1624	1785
37/14	0·080	0·560	0·1906	0·1315	2203
37/13	0·092	0·644	0·2521	0·09947	2914
37/12	0·104	0·728	0·3221	0·07783	3723
37/11	0·116	0·812	0·4008	0·06265	4633
37/10	0·128	0·896	0·4880	0·05138	5641
37/9	0·144	1·008	0·6176	0·04060	7140
37/8	0·160	1·130	0·7625	0·03288	8815
61/24	0·022	0·198	0·02378	0·0551	275
61/23	0·024	0·216	0·02831	0·8865	327
61/22	0·028	0·252	0·03854	0·6583	446
61/21	0·032	0·288	0·0503	0·4287	572
61/20	0·036	0·324	0·0637	0·3940	736
61/19	0·040	0·360	0·0786	0·3191	909
61/18	0·048	0·432	0·1132	0·2216	1309
61/17	0·056	0·504	0·1541	0·1628	1781
61/16	0·064	0·576	0·2013	0·1246	2327
61/15	0·072	0·648	0·2548	0·09850	2945
61/14	0·080	0·720	0·3145	0·07979	3636
61/13	0·092	0·828	0·4160	0·06033	4809
61/12	0·104	0·936	0·5316	0·04721	6145
61/11	0·116	1·044	0·6614	0·03795	7646
61/10	0·128	1·152	0·8053	0·03116	9309
91/18	0·048	0·528	0·1692	0·14857	1956
91/17	0·056	0·616	0·2302	0·10915	2661
91/16	0·064	0·704	0·3007	0·08357	3476
91/15	0·072	0·792	0·3806	0·06603	4400
91/14	0·080	0·880	0·4699	0·05348	5432
91/13	0·092	1·012	0·6215	0·04044	7185
91/12	0·104	1·144	0·7942	0·03164	9181
91/11	0·116	1·276	0·9881	0·02543	11422

Weight of 100 feet of wire of different metals.

Gauge No.	Thickness S. W. G.				Thickness B. W. G.			
	Iron.	Steel.	Brass.	Copper.	Iron.	Steel.	Brass.	Copper.
..	..	..	..	..	30·58	30·92	33·43	35·17
1	23·4	24·0	25·7	26·8	25·75	26·04	28·15	29·62
2	19·6	20·1	21·6	22·5	21·34	21·57	23·32	24·54
3	16·4	16·8	18·1	18·8	18·02	18·22	19·70	20·72
4	13·8	14·3	15·2	15·8	15·11	15·28	16·52	17·38
5	11·6	11·9	12·7	13·4	12·46	12·59	13·62	14·33
6	9·5	9·7	10·5	10·9	11·45	11·57	12·51	13·16
7	8·0	8·2	8·8	9·2	9·25	9·35	10·11	10·64
8	6·6	6·8	7·3	7·6	7·29	7·37	7·97	8·38
9	5·3	5·4	5·8	6·1	6·60	6·68	7·22	7·59
10	4·23	4·34	4·65	4·99	4·96	5·02	5·43	5·71
11	3·46	3·55	3·80	4·00	4·13	4·18	4·52	4·75
12	2·80	2·87	3·08	3·22	3·14	3·18	3·43	3·61
13	2·16	2·22	2·37	2·48	2·34	2·36	2·55	2·69
14	1·66	1·70	1·83	1·91	1·69	1·71	1·85	1·95
15	1·33	1·36	1·46	1·53	1·37	1·39	1·50	1·58
16	1·06	1·08	1·16	1·22	1·05	1·06	1·15	1·21
17	·80	·82	·88	·92	·80	·81	·87	·92
18	·60	·62	·66	·69	·61	·62	·67	·70
19	·40	·41	·44	·46	·47	·48	·51	·54
20	·33	·34	·36	·38	·32	·33	·34	·37

In order to find the section of wire required between two stations when the values of current, E. M. F. and the distance betwen two stations is known, use

$$R=\frac{E}{C}$$

Also resistance increases or decreases as the length of the wire increases or decreases. If L=length of wire

then the value of R for 1000 yards $=\dfrac{R\times 1000}{L}$.

See this value in column No. 5 in the tables above. (Resistance at 60° F. per 1000 yards) and find the area of wire and its number against the result. In case the temperature is other than 60°, then corect for 60°.

Example.—It is required to connect two stations 100 feet apart. The current flowing is 15 amps. and its E. M. F. = ·5 volts. Find the section of the wire.

Length of wire $= 2 \times 100 = 200$ feet.

$$\text{Resistance} = \frac{E}{C} = \frac{\cdot 5}{15} = \frac{1}{30}\text{ Ohm.}$$

$\therefore$ for a length of 3,000 feet, $\text{Resistance} = \frac{3000 \times 1}{200 \times 30} = 0{\cdot}5$ ohm.

By looking at the table we find the following :—

Resistance at 60° F.	·5257	·5228	·5262	·4987
Area in square inches	·0474	·0478	·0476	·0503
Diameter of the strand	·276	·280	·280	·288
Do. each wire	·092	·056	·040	·032
No. of S. W. G.	7/13	19/17	37/19	61/21

Use any of the above 4 wires but 19/17 is best both as regards cost and resistance.

OVER HEAD TRANSMISSION LINES.

Size of Copper Conductors.

$$A = \frac{\text{Killo-watt} \times \text{length (L)} \times K.}{E^2 \times \text{loss per cent.} \times \text{P. F.}}$$

Where—A = Sectional area of conductor in square inches.
L = Length in yards.
E = Voltage at feeding point.
P. F = Power factor which varies from ·7 to ·95 ; average value = ·8
K has following values.

For continuous current or single phase A. C. :—

For single conductor .. .. = 2·5
For two conductors, *i. e.* 2 wire system .. .. .. = 4·9
For 3 wire system .. .. = 1·25

In practice the neutral or middle wire is taken as half the area of an outer wire.

For alternating Current :—

Each conductor of 2 phase 4 wire system	..	.. =2·5
Each conductor of 3 phase mesh ..	..	.. =2·5
Each conductor of 3 phase star connection	..	.. =2·5

The modern movement towards the production of electricity in bulk in the Hydro-Elecric Stations and its distribution over wide areas has given increased importance to overhead lines.

Example.—Find the size of wire required for delivering 1000 K. W. at a distance of 8000 yards from the generator at a pressure of 6285 volts with 5 % line loss.

∴ Initial pressure=6600 volts.
and the power at generator will be=1050 K. W.

$$\therefore \text{Current} = \frac{1050}{6600} = 159 \text{ amp.}$$

1. *For direct current*= $\dfrac{\text{Amp.} \times \text{Distance in yards.}}{2000 \times \text{Line drop in V.}}$

$$\text{Area} = \frac{159 \times 8000}{2000 \times 315} = \cdot 202 \text{ sq. inch.}$$

2. *Three phase transmission by general formula.*

$$A = \frac{1000 \times 8000 \times 2 \cdot 5}{6285 \times 6285 \times 5 \times \text{P.F.}} = \frac{\cdot 101}{\text{P. F.}}$$

By substituting the value of the P. F. the size of the wire in square inches can be found out.

3. *Three phase with neutral :—*

As the voltage is between any wire and the neutral, its value $= \dfrac{6285}{\sqrt{3}} = 3630$

$$\text{and Load} = \frac{1000}{3} \text{ K. W.}$$

If the P. F. = ·9, the apparent load $= \dfrac{333 \cdot 3}{\cdot 9} = 370.$

$$\therefore \text{Current} = \frac{370 \times 1000}{3630} = 102 \text{ amps.}$$

Now line drop at 5% of 3630=181 volts.

$$\therefore \text{Total Resistance} = \frac{181}{102} = 1 \cdot 78 \text{ ohm. for 8000 yards } \therefore \text{R. per 1000}$$

yards = ·222 ohms.
See tables 3/0 S. W. G. copper wire will do.

Strength of Poles.

In calculating the strength of poles required for any overhead line the wind pressure on the whole structure, including wires and poles, has to be considered.

The following is the formula for calculating wind pressure on wires:—

$F = \cdot 0556 \times d \cdot \times p \times n \times L.$

Where F=wind pressure on wires of span.
L=length of Span in feet.
d=diameter of wire in inches.
n=number of wires.
p=Max. assumed wind pressure depending on locality in India.
Wind pressure on pole=Total height $\times \cdot 0556\ d \times p.$

Table of wind pressure on various wires assuming $P=15$
20 and 25 lbs. per sq. foot.

Span.	10 S.W.G.			8 S.W.G.			4 S.G.W.			2 S.W.G.			1/10 S.W.G.		
	P. in lbs.														
	15	20	25	15	20	25	15	20	25	15	20	25	15	20	25
150	16	21·3	33·	2[illegible]	26	33·2	29	38	48	34	46	57	41	54	67
210	22	30	47	28	37	47	41	54	68	48	64	81	57	75	95

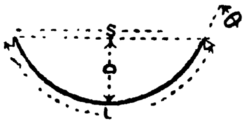
How to find the Sag of the Conductor.

Let S=span of wire in feet.
L=length of wire in feet at minimum dip.
W=total pressure on wire in lbs. per foot.
$W = \sqrt{w^2+p^2}$ where w=weight of wire in lbs. per foot, and
P=wind pressure per foot length in lbs.
$P = \cdot 0556 \times d \times p$ where d=dia. of wire in inches, and
p=wind pressure lbs. per square foot take 25 lbs. for Great Britain but about 40 to 50, and more, in cyclones, etc.
T=maximum stress lbs. on wire at insulators$=Ba \div F$.
B=ultimate breaking stress of hard drawn copper wire;
=50,000 to 60,000 lbs. per sq. in. for wires larger than No. 1 S. W. G., or 60,000 to 65,000 lbs. for wires smaller than No. 1 S. W. G., but this varies with the degree of hardness to which the wire is drawn.
F=factor of safety, taken generally at 4 or 5, but in countries where snow and ice burden wires, a safety factor of 6 to 7 is not uncommon.
a=cross sectional area of wire in square inches.

D=minimum dip in feet, that is, the dip at lowest temperature to be experienced where wire is erected.

$D = \frac{S^2 \times W.}{8\ T}.$

$L = S + \frac{8\ D^2}{3\ S}.$



L^1=length of wire in feet with maximum dip.

$L^1 = L + (L \times \cdot 00000956 \times t)$ where ·00000956 is the length expansion coefficient of copper per degree Fah.

t=temp. (in degrees Fah.), rise above the lowest temp. to be experienced.

D^1=max. dip. experienced=$\sqrt{\frac{(L^1 - S) \times 3S.}{8}}$ (*Molesworth.*)

It is not necessary for most small projects to work out this in detail, but it will always be necessary to do so in case of transmission lines involving long spans.

Cost of Transmission Lines.

This depends on many things, such as type of posts, size of wires, pressure of the line, etc., but the average price where lattice posts are used and where the size of the wires used is from No. 8 S. W. G. to No. 1 S. W. G., varies from Rs. 6,000 to Rs. 10,000 per mile.

Care should be taken that the brackets for the posts are so designed that a bird while sitting on it cannot earth the wire.

Table giving Dips and Strains for 150 feet spans for all guages.
Worst Temperature 22° F., no wind factor of safety 4.

Temperature F°.	Dip Inches.	Strain (lbs.)				
		10 S.W.G.	8 S.W.G.	4 S.W.G.	2/0 S.W.G.	4/0 S.W.G.
22	9	190	295	620	1375	1820
32	14	121	2[illegible]0	..	..	..
42	17·7	96	148	310	700	920
52	20·6	82	126	265	600	800
62	23·2	72	112	235	520	700
72	25·8	66	100	215	480	630
82	28	60	94	197	440	590
92	30	53	88	184	415	550
102	32	52	80	..	..	..
112	34	50	..	..	..	..
182	44	..	..	..	..	..
Breaking Strain ..		830	1260	2560	5430	7030

When wires are erected, they should be pulled up either to the dips or the strains calculated for the temperature at the time of erection.

Stresses on poles at angle.

$$S = 2 \times p \times \text{Cos}\frac{a}{2}$$

Where S = resultant horizontal stress (lbs.)
p = total working stress of wires in line.
a = horizontal angle enclosed by wires at point of change of direction.

Strength of stays.

$$W = \frac{S}{\text{Sin } b.}$$

Where W = stress in stay wire (lbs.).
S = resultant horizontal stress on pole.
b = vertical angle between stay wire and pole.

POLES.

Hamilton sectional steel poles are used by India Telegraph Department and are suitable for electric power lines where carriage is of difficult nature. They are not suitable for permanent electric power. Steel tubular poles are largely used. It is desirable to lap the buried ends of steel poles with tarred gunny as a preservative.

Steel lattice poles built up of angle or channel section with cross bracings are suitable for special terminal construction or transmission lines along roads.

Reinforced concrete poles are also used. They are cheap and easy to manufacture; but require careful supervision in construction and great care in erection.

Tensile Strength and Conductivity of Wires.

Description of wire.	Tensile strength in tons per sq. inch.		Conductivity per cent.	
	From	to	From	to
Silicium-Bronze Telegraph and Electric Light wire, High conductivity ..	29	33	90	96
Silicium-Bronze Telephone line wire for long distances	40	50	34	40
Silicium-Bronze Telephone (local) and spring wire	50	65	20	30
Phosphor-Bronze wire	40	65	20	30

Tensile Strength and Conductivity of Silicium Bronze and Phosphor Bronze Wire.
The diameter in each case being 1 millimetre.

Description of wire.	Tensile strength in tons per square inch.	Resistance per mile in Ohms.	Relative conductivity.
Pure copper	17·78	33·1	100
Silicium-Bronze (Telegraph) ..	28·56	34·5	96
„ „ (Telephone) ..	48·25	103	34
Phosphor-Bronze („) ..	45·71	124	26
Swedish Galvanized Iron	22·86	216	16
Galvanized Bessemer-steel	25·40	249	13
Siemens-martin steel	26·67	266	12

Electric Lighting and Fans.

$$\text{Current taken by a lamp} = \frac{\text{Watts}}{\text{Volts}}.$$

Example.—A 220 Volt, 30 Watt lamp takes $\frac{30}{220}$ or 14 amp. (approx.).

Table showing total number of units consumed by a lamp in 30 days.

Daily use in hours.	Size in Watts.									
	10	20	30	40	50	60	100	130	150	200
1	·3	·6	·9	1·2	1·5	1·8	3·0	3·9	4·5	6·0
2	·6	1·2	1·8	2·4	3·0	3·6	6·0	7·8	9·0	12
3	·9	1·8	2·7	3·6	4·5	5·4	9·0	11·7	13·5	18
4	1·2	2·4	3·6	4·8	6·0	7·2	12	15·6	18	24
5	1·5	3·0	4·5	6·0	7·5	9·0	15	19·5	22·5	30
6	1·8	3·6	5·4	7·2	9·0	10·8	18	23·4	27·0	36
7	2·1	4·2	6·3	8·4	10·5	12·6	21	27·3	31·5	42
8	2·4	4·8	7·2	9·6	12·0	14·4	24	31·2	36·0	48
9	2·7	5·4	8·1	10·8	13·5	16·2	27	35·1	40·5	54
10	3·0	6·0	9·0	12·0	15·0	18·0	30	39·0	45·0	60
11	3·3	6·6	9·9	13·2	16·5	19·8	33	42·9	49·5	66
12	3·6	7·2	10·8	14·4	18·0	21·6	36	46·8	54·0	72

I.C.P. = 1·7 to 2 Watts (for metallic filament lamps).
I.C.P. = 3 to 3·5 Watts (carbon filament lamps).

Consumption per day.

At hours.										
1	.01	.02	.03	.04	.05	.06	.10	.13	.15	.20
3	.03	.06	.09	.12	.15	.18	.30	.39	.45	.60
5	.05	.10	.15	.20	.25	.30	.50	.65	.75	1.00
9	.09	.18	.27	.36	.45	.54	.90	1.17	1.35	1.80
11	.11	.22	.33	.44	.55	.66	1.10	1.43	1.65	2.20

Electric Fans, Power Consumption in Units and Current.

Type.	General size.	Units per hour.	Current Consumed at	
			110V.	220V.
Ceiling ..	100	0·1	·9 A	·45 A
	120	0·12	1·1 A	·55 A
	150	0·15	1·3 A	·67 A
	180	0·18	1·6 A	·82 A
	200	0·20	1·8 A	·91 A
Table ..	80	·030	·28 A	·14 A
	60	·060	·54 A	·27 A
	75	·07	·68 A	·34 A

Current Pressure and Power.

D. C. in K. Watts *A. C. 3- phase in K. V. A.*

Amps.	110V.	220V.	500V.	110V.	230V.	400V.
1	·11	·22	·5	·191	·397	·692
2	·22	·44	1	·381	·794	1·384
3	·33	·66	1·5	·572	1·19	2·07
4	·44	·88	2	·764	1·588	2·768
5	·55	1·1	2·5	·955	1·985	3·460
6	·66	1·32	3	1·14	2·382	4·152
7	·77	1·54	3·5	1·33	2·78	4·844
8	·88	1·76	4	1·52	3·176	5·536
9	·99	1·98	4·5	1·71	3·573	6·228
10	1·1	2·2	5	1·90	3·97	6·92
20	2·2	4·4	10	3·80	7·95	13·84
50	5·5	11	2·5	9·5	19·85	34.6
100	11	22	50	19	39·7	69.2
200	22	44	100	38	79·4	138·4
500	55	110	250	95	198·5	346

For H. P. multiply the K. Ws. × 1·34. In A. C. multiply the K. V. A. first by the power factor to get K. Ws.

USEFUL TABLES FOR FANS.

Standard Speed.

Size inches.	R. P.M.	Power required, Watts.	B. of T. units per hour.	Output c. ft. per min.	Area of fan in sq. ft.
9″	1350	25	·025	400	·5
12	1000	40	·04	800	·8
15	800	60	·06	1200	1·2
18	650	75	·075	1700	1·7
21	575	100	·1	2400	2·4
24	500	130	·13	3000	3·1
30	400	200	·2	5000	4 9
36	350	275	·275	7000	7·0
42	300	375	·375	10,000	9·6
48	250	450	·45	12,000	12·5
54	225	575	·575	15,000	15·9
60	200	700	·7	19,000	19·6
66	180	850	·85	23,000	23·8
72	175	1,000	1·0	28,000	28·2

USEFUL TABLES FOR FANS.

High Speed.

Size inches.	R.P.M.	Power required, Watts.	B. of T. unit per hour.	Output c.ft. per minute.	Area of fan in sq. ft.
9	2400	100	·1	700	·5
12	1800	150	·15	1,450	·8
15	1400	200	·2	2,100	1·2
18	1200	275	·275	3,200	1·7
21	1000	350	·35	4,200	2·4
24	900	475	·475	5,400	3·1
30	700	700	·7	8,500	4·9
36	600	1,000	1·0	12,000	7·0
42	500	1,350	1 35	16,000	9·6
48	450	1,750	1·75	21,000	12·5
54	400	2,200	2·2	27,000	15·9
60	360	2,700	2·7	34,000	19·6
66	325	3,300	3·3	42,000	23·8
72	300	4,000	4·0	48,000	28·2

Lighting of Streets and Roads.

Illumination varies inversely as the square of the distance, *i.e.*, one C. P. gives one unit at a distance of 1 foot, 16 C. P. gives one unit at 4 feet, and 100 C. P. gives one unit at 10 feet.

Average Minimum Illumination.

Main thoroughfares	·05 candle feet.
Side streets	·025 candle feet.
Suburban streets	·005 candle feet.

(*Molesworth*).

Table showing the Intensity of Illumination required in different places.

Places.	Foot Candles Required.
Auditoriums, Theatres	1 to 3
Bookkeeping	3 „ 5
Corridors, Halls	·5 „ 1
Assembly Halls and Churches	·75 „ 1·5
Drafting Rooms	5 „ 10
Desk Lighting	2 „ 5
Engraving	5 „ 10
Factories, General, where individual drops are used ..	2 „ 3
„ Complete, no individual drops	4 „ 5
Hotel Halls	1 „ 5
„ Rooms	2 „ 3
Offices (Waiting Rooms)	1·25 „ 2·5
„ (Private)	2 „ 3
„ (General)	3 „ 4
„ (where desk lights are used)	1·5 „ 2·5
Post Offices	2 „ 5
Reading	1 „ 3
Residences	1 „ 3
Shops (Light Goods)	2 „ 3
„ (Dry Goods)	4 „ 6
„ (Clothing)	4 „ 7
Shop Windows	5 „ 20
School Rooms	2 „ 3
Saloons, Cafes, depending on effects	2 „ 5
Stations (Waiting Rooms)	1·5 „ 2·5
Train Sheds	1·5 „ 2
Warehouses	1·5 „ 2

Arc Lamps.

Arc lamps are more economical, giving about 6 times the light for the same consumption of electricity. For indoor use 7 ampere continuous or 11 ampere alternating arc lamps and for out-door use not less than 10 ampere continuous or 15 amps. alternating current. Arc lamps are best burnt in series. An arc lamp requiring a current of 10 amps. at an E. M. F. of 50 volts will give a light of 1,000 to 1,500 candles, and will require approx. 1 H. P. to supply it. They are most economical for street lighting. The smallest size requires 6 amp. at 50 volts giving 300 C. P. uses 3 B. O.T. and should be 30 feet high and 240 feet apart.

Fuse Wires.

Fuse Wire.	Fusing Current (Amperes).			Fuse Wire.	Fusing Current (Amperes).		
S.W.G.	Coppe.	Tin.	Lead.	S.W.G.	Copper.	Tin.	Lead.
50	·324	These sizes are inconveniently small for tin and lead wires.		30	14·1	2·27	1·90
49	·426			29	16·2	2·60	2·19
48	·656			28	18·4	2·96	2·48
47	·916			27	21·5	3·45	2·90
46	1·20			26	24·7	3·97	3·33
45	1·52			25	29·0	4·64	3·90
44	1·85			24	33·4	5·36	4·50
43	2·21			23	38·1	6·11	5·13
42	2·59			22	48·0	7·69	6·46
41	2·99			21	58·6	9·40	7·89
40	3·41	·546	·459	20	70·0	11·2	9·42
39	3·84	·616	·517	19	82·0	13·1	11·0
38	4·76	·763	·641	18	108·0	17·3	14·5
37	5·74	·921	·773	17	136·0	21·8	18·3
36	6·79	1·09	·914	16	166	26·6	22·3
35	7·89	1·26	1·06	15	198	31·7	26·6
34	9·04	1·45	1·22	14	232	37·2	31·2
33	10·2	1·64	1·38	13	286	45·8	38·5
32	11·5	1·84	1·55	12	344	55·1	46·3
31	12·8	2·05	1·72	..	..	..	..

Heating and Cooking by Electricity.

The therm or gramme calorie is the C. G. S. Unit of heat, and is represented as the quantity of heat required to raise one gramme of water, 1 degree centegrade.

Therms $\times 0\cdot003968$ give B. Th. units.

The British thermal unit is the heat required to raise one pound of water 1 degree Fahrenheit.

B. Th. unit $\times 251\cdot996$ gives gramme calories.
,, ,, $\times .251996$ gives kilograme calories.
,, ,, $\times 778$ give feet lbs.
,, ,, per second $\times$ $1\cdot4146$ give H. P.

A current of 5 amps. at 200 volts will raise one pint of water in a well-designed electric kettle from 60° F., to boiling point in about 4 minutes.

The time required to boil a given quantity of water with a heater of known wattage is approximately given by the formula.

Time in minutes $= 3700 \times$ pints $\div$ watts........(Kemp).

DYNAMOS AND MOTORS.

Electrical energy is mainly utilised by means of *Dynamos* and *Motors.*

Dynamos are machines by which *mechanical energy* is transferred into *electrical energy* at the point where the source of mechanical energy is located.

Motors are machines by which *electrical energy* is transferred into *mechanical energy* at the point where it is meant to be utilised.

The use of *Dynamos* and *Motors* is due to the simplicity and efficiency of electrical connections and the enormous economy of energy in its transmission at long distances.

I.—*To find power required to drive a Dynamo*—

If *a Dynamo* gives an output of 100 *amperes* at an electric pressure of 100 *volts*, with a *commercial* efficiency of 85 %, the power required to drive it $= 100 \times$

$$100 \times \frac{100}{85} \text{ watts} = \frac{1000000}{85 \times 746} \text{ B. H. P.} = 15\cdot7 \text{ B. H. P.}$$

As there is always a certain amount of power required to overcome the friction, &c., it is necessary to make a still further allowance of about 15 % in large engines and of about 25% in small engines between the B. H. P. and the I. H. P.

II.—*To find the power available from an electric motor*—

The actual power required at the terminals of a motor to give one effective B. H. P. at its spindle depends upon the efficiency of the motor, which varies from 85 to 92%. If, therefore, the efficiency is 85% watts required at the terminals to give one B H. P. at the spindle

$$= 746 \times \frac{100}{85} = 877\cdot7, \text{ say } 900 \text{ watts.}$$

It is usual to supply power to a motor at the rate of $\cdot1$ kilowatt per rated Horse-power.

III.—To find the electric pressure or watts lost in resistance of the cables—

The volts lost in a cable=the product of resistance in o.h.m.s. and the current flowing through the cable=CR.

It must be remembered that the length of the cable is double the distance between the dynamo and the motor to allow of the return conductor, and the resistance should be calculated accordingly.

Example.—To find the loss on volts in a 19/16 cable, (*i.e.*, a cable composed of 19 wires each of No. 16 S. W. G. or 0·064 inch in diameter) one mile in length with a current of 30 amperes.

Resistance of 1000 yards of cable=4002 o.h.m. (page 580).

$$,, \quad 1 \text{ mile} = \cdot 4002 \times \frac{1760}{1000} = \cdot 7044 \text{ o.h.m.}$$

$\therefore$ volts lost=.7044×30=21·13 volts.

In a current density of 1000 amperes per square inch sectional area of pure copper conductor, the loss in volts=5 volts per 100 yards route, *i.e.*, 2½ volts in flow, and 2½ volts in return, or more accurately 86 volts per mile route.

Every 100 cubic inches of copper absorbs 1 H. P. approximately.

IV.—To find the loss of power in a watts in a given cable—

Watts lost=C^2R. Where C=current in amperes.
R=Resistance in o.h.m.s.

Example.—To find the watts lost in a mile of 19/16 cable when carrying a current of 30 amperes.

Watts lost=$(30)^2 \times .7044$=633·96 watts. (See example above).

Thus to find out the capacity of the various pieces of an Electrical Plant, we should proceed from the power required at the spindle of the motor to the watts required at its terminals; then allowing for the resistance, we should find out the Brake Horse-power required at the dynamo pulley, and finally calculate the Brake or the Indicated Horse-Power of the engine required to run the dynamo.

Example.—Find B. H. P. required to drive a 10 kilowatts dynamo, the efficiency of the same being, say 80%.

$$\text{B. H. P. on dynamo pulley} = \frac{10 \times 1000}{746} \times \frac{100}{80} = 16{\cdot}76 \text{ B. H. P.}$$

Which=20·95 I. H. P.
I. H. P. is taken 25% extra on the average.

Efficiency of Transformers.

OUTPUT.	NO LOAD IRON LOSSES.		EFFICIENCY %.				
K. Ws.	W.	% of full load.	Full Load	¾ load.	½ load.	¼ load.	$\frac{1}{10}$ load.
1	40	4·0	93·5	93	91·2	85	71
5	75	1·5	96·3	96·2	95·8	94·0	86·7
10	100	1·0	96·5	96·5	96·4	95·5	91·0
20	180	·9	97·0	97·0	97·0	95·8	91·5
50	400	·8	98·0	98·0	98·0	96·8	92·3
100	700	·7	98·2	98·2	98·2	97·0	93·2

I.—*Direct current Efficiency of Motors.*—

Output B.H.P.	..	1	2	[illegible]	5	10	20	25	50
Efficiency %	..	77	82	8[illegible]	84	86	87	89	91
Output B.H.P.	..	7[illegible]	100	15[illegible]	200	..	..	..	..
Efficiency %	..	9[illegible]	92	9[illegible]	93	..	..	..	..

II.—*A. C. Polyphase Induction Motors.*—

B. H. P	10	20	50	100	150	200	250	300
Efficiency	86	88	89	90	91	92	92	93

Efficiency of Dynamo.

Output in K. Ws.	Exciting watts % of full load.	Losses in armature % of full load.	Full load elect. efficiency.	Full load commercial efficiency.	Combined efficiency of engine and dynamo.
1	9	5	86	78	60
10	4½	3½	92	85·5	71
100	1¾	2¼	96	93	84
500	1	1½	97·5	94·5	85

Electric Generating Stations.

Alternating current is suitable for large scattered areas.

High pressure direct current with rotary transformers to reduce pressure is applicable to scattered areas. Low pressure direct current produces and distributes electricity at the same pressure at which it is supplied to the consumers.

The direct current system permit the use of storage batteries, which cannot be used with alternating currents; greater efficiency in distribution and greater adaptability to motive power.

The works being liable to sudden demands, the quick steaming qualities of the water tube type of boilers are of great advantage. Engines of the marine type are preferred for large outputs. Storage by secondary batteries is expensive, but is used by a few works for maintaining the supply after midnight.

Lancashire boilers in conjunction with water, tube boilers make the best arrangement for a central station.

Cost of Generating Electricity.

The cost of producing a unit of electricity reaches its minimum with a plant capable of serving not less than 12,000 (16 C P.) lamps and as not more than $\frac{2}{3}$ of the number installed will ever be in use at one time, the above plant will allow of 18,000 lamps being fixed. (Adams).

Power required for electric lighting under good conditions the Engine power required equals—

Gas filled	..	..	..1000/1800.
Arc Light one K.W.=		..	..1000 C. P.
Metal Filament	..	..	..600/1000.

Ordinarily one H. P. will supply 16. 20 candle power incandescent lamps; 30 watts per 20 C. P. lamp is considered very economical, the Nernst lamp is said to give 40 C. P. for 60 watts.

Lightning Conductor.—

Conductor should be preferably of copper, weighing not less than 6 ozs. per foot run, the conductivity of copper being not less than 90 % of the pure metal: should be either in the form of tape or rope of stout wires, no individual wire being less than No. 12 B. W. G. Every joint should be well soldered.

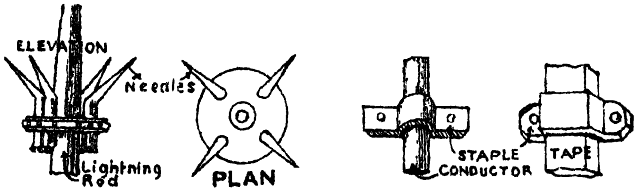
A copper tape $\frac{3}{4}$ to 1 inch is quite sufficient for a conductor 80 feet long. Iron may be used but should not weigh less than $2\frac{1}{4}$ lbs. per foot run.

Earth connection.—Depend on the area of the building. Two at least are required. Earth plates should not be less than 9 square feet in area and $\frac{1}{16}$ inch thick, burried in permanently wet earth and surrounded by characoal and carbon. Resistance of earth should not exceed 5 o.h.m.s.

Two main lightning rods, one on each side of the building should be provided. Horizontal conductors should connect all the vertical rods.

Points.—The point of the terminal should not be sharper than a cone of which the height is equal to the radius of its base, but a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be

fixed 3 or 4 sharp copper points each about 6 inches long. The points are arranged at equal angles, thus 3 points will have 120° each, 4 points 90° each and so on as shown below.



Joints in series of conductors should be as few as possible. Connections between the verticals and horizontals should be in an accessible place. They should be well cleaned and thoroughly soldered. Iron rods whether galvanized or not should be painted. Copper rods may be painted or not.

Thorough inspection and testing of all conductors and earth connections should be made after erection. The whole system should be kept in good order. It is better to have no lightning conductors than inefficient ones.

Copper rods to the height of 10 feet above ground can be enclosed in an iron pipe to avoid risk of injury and theft.

Testing.—

The tests are of two kinds :—

(1) A visual test.

(2) An electrical test.

(1) *Visual test.*—All joints and connections above ground should be examined visually and where there are any obvious loose joints or disconnections they should be repaired.

The points of the lightning rods should be examined. if accessible and the following should be noted.—

(*a*). That the test lead, if fitted has not become detached, but is finally soldered on.

(*b*). That the points are firmly fixed to the lightning rod. If loose or unscrewed they should be secured;

(*c*). That all joints are not only firm but maintaining thei ntimate contact of bright metal to bright metal required in lightning conductors. In case of any looseness, joints should be remade and metal brightened at the contacts.

It should be noticed whether any of the staples fastening conductors to walls have come away, and it should be ascertained that the strips connecting metal roofs, etc., to the conductors are secure.

The following should be observed before carrying a test :—

(*a*). Any neighbouring watermain should be connected to the system below the surface of the ground, whether required for the earth or not.

(*b*). All neighbouring masses of metal water, or other conducting substances in proximity to the conductors should be connected to them.

(*c*). Same kind of metal should be used throughout the system.

Electrical test.—Use Bridge, Megger for the electrical test.

ARBORICULTURE.

Methods by which Trees are Propagated.

(1) Sowing the seed in the places where it is intended the trees should grow.

(2) Sowing the seed in the nursery or in pots or baskets and when old enough planting the young trees in the required places.

(3) Planting cuttings from trees direct where the trees should grow or in a nursery and when they have formed roots, transplanting them to the required places.

(4) Detaching and planting in required places the roots which spring up round certain kinds of trees.

(5) Obtaining rooted branches by the method of layering and planting these in the required place.

(6) Grafting branches or buds on to the stem or branches of other trees of similar kinds.

(7) Felling certain kinds of trees so that they send out coppice shoots having independent roots.

Collection and Preservation of Seed.

(1) As far as possible the seed should be good and fresh.

(2) The seed should on no account be collected before it is ripe and collected before it begins to fall on the ground.

(3) The seed should be gathered in dry weather and should immediately be pread out to dry in the shade.

(4) After drying, the seed should be cleaned, that is, the useless outer envelopes should be removed.

(5) Seeds which have passed through the bodies of birds and animals generally germinate very well, and should be collected when practicable.

(6) It is best to sow seed as soon as collected, especially when the seeds are oily.

(7) When the seed does not ripen at a suitable time for sowing and has to be kept until the time arrives, it must be carefully preserved from damp and the attacks of insects and vermin.

(8) The best way is to spread it loosely on a *pacca* floor and turn it over from time to time.

(9) To keep off insects new leaves may be mixed with the seed.

(10) Where rats and mice are common the seed may be stored in *gharas* or boxes or in sacks or baskets suspended from the roof in a well ventilated room.

(11) Wet seed should on no account be used.

(12) To test its quality, place a number of seeds on a red-hot iron *tawa*. The sound seeds will burst before burning.

A better method is to place a number of seeds in a pot of earth, keep them moist and put them in a warm place in the dark. The sound seed will germinate in a short time.

As a rule the method of direct sowing is not to be recommended. Direct sowings may be either broad cast or partial.

Broad Cast Sowings.

The seed is scattered evenly all over the area to be operated on. The soil must first be cleaned of *jungle*, etc., and then worked up by ploughing.

The first ploughing should be done at least six months before the time of sowing and the soil should be turned over several times in this interval. The end of the rains is the best time for the first ploughing.

Sowing in Nurseries.

(1) The soil should be of best quality, such as would produce good crops. Sandy soils when matured do well, but stiff clay soils and salt soils should be avoided and a nursery should not be established where there is a kankar bed below the surface.

(2) The nursery should be of regular shape, if possible rectangular because it is easier to lay out necessary water channels. It is necessary to manure the soil. In sandy soils, spread clay taken out from bottom of tanks; the best manure is the vegetable mould whose leaves and weeds have become thoroughly decayed. Such manure should be made in every nursery in pits, 2 or 3 feet deep. It is essential to add dung of animals or bones.

The manure required is from 3 to 4 hundred maunds per acre.

(3) The seed should be sown evenly and thinly, and then covered with earth to a proper depth, which should not be more than twice the thickness of seed itself. Water every day.

(4) The best time for sowing is the early spring. In places where the rainfall is abundant, the beginning of rains is the best time.

Preservation of Seedlings, etc.

(1) Shading the seed beds from mid-day sun and frost night.

(2) When the seedlings are too thick they must be thinned out as they grow. As the seedlings approach the height of 3 feet there should be a clear space of 2 feet between each seedling.

(3) A cheap and expeditious way of lifting plants from the seed beds when the seedlings have been sown in drills, is to dig a trench at a short distance and parallel to each line of seedlings. The plants can then be pushed into the trenches helped by the spade from behind.

(4) The best season for transplanting is the cold weather but in dry districts where irrigation is not possible, this should be done in rainy weather.

(5) Seedlings may often be raised from seed sown in flower pots or baskets. It is safe from the attack of birds and vermin.

(6) As soon as the seedlings are large enough to handle easily they should be put singly into pots, 4 inches diameter at the top and as soon as the roots have reached the sides of the pot the plant should be shifted into a bigger one, 6 or 8 inches diameter. Water should be given as often as the earth gets dry and before the plant begins to droop.

Propagation by Cuttings.

(1) The cold weather and the rains are the best times for making cuttings. Such cuttings should be from 5 to 10 feet long, with the lower end cut obliquely and should be set 2 or 3 feet in the ground in prepared holes and the upper end plastered over with cowdung and clay.

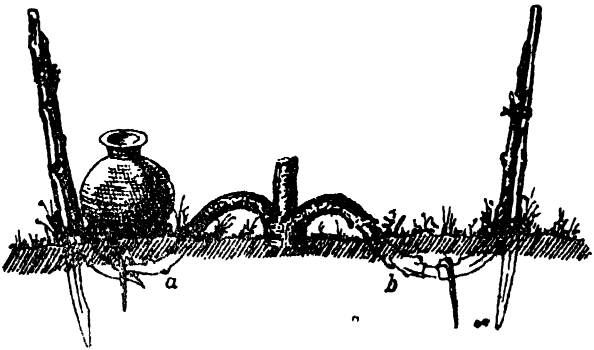
Reproduction by Root Suckers.

Suckers may be dug up and cut away from any tree which sends them up, but the best way to get them is to cut down an old but healthy tree, carefully fence it in, and water the ground round its stump.

The suckers take 2 years or more to grow to size fit for planting out. They require a good deal of watering at first. Except plantain no other tree should be planted. *Ber* or *jaman* can be planted in this way.

Layering.

Mangoes, *Loquats*, etc., are very generally reproduced by this method. To produce a tree by this method, the branches are bent downward until they can be brought in contact with the soil and the tree is left alone for a season, after which most of the branches so treated will be found to have taken root at the point of contact with the soil. A slit should be cut in the branch being layered at the bent part where it touches the soil, by drawing a knife obliquely across it on the lower side below a bud, upwards for about an inch, towards the end of the branch. This slit should be kept open by placing a small stone in it. A *ghara* of water, with a small hole for a drip should be placed over each layer to keep the soil almost wet.

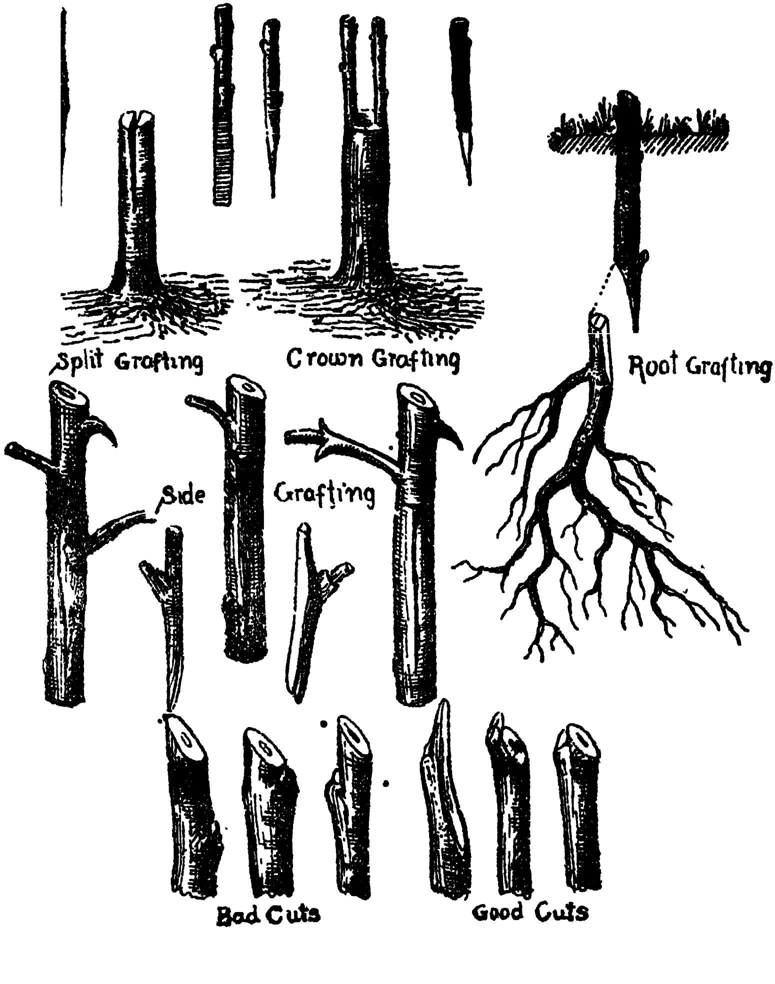


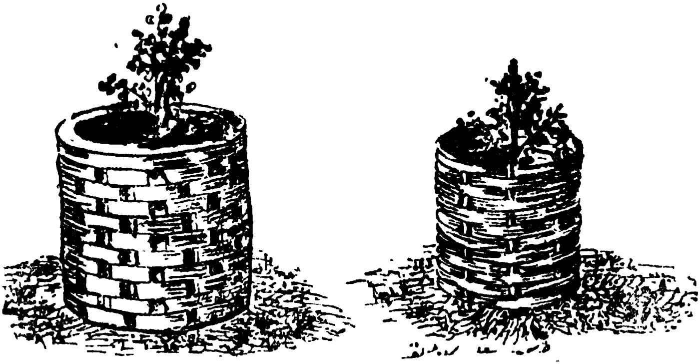
Grafting.

Grafting consists in laying bare with a sharp knife the growing portion which lies between the back and wood of a branch.

The proper season for grafting is spring, *i. e.*, immediately before fresh growth takes place.

Methods of Grafting.





Fencing.

The following are the chief kind of fences in use to avoid their being injured by men and cattle.

(1) A dry thorn hedge.
(2) A mud wall.
(3) Wire fencing.
(4) A wattle fence commonly used where branches of trees or other suitable material is available.
(5) An open work brick wall (see sketch).
(6) Iron guards.
(7) Basket guards. (See sketch above).

Thinning and Pruning.

As the trees get taller, their number per acre should be reduced.

The best season for making thinnings in the plains is the cold weather, and in the hills, the early summer.

Pruning, although sometimes necessary, should be avoided when possible. The trees should be pruned while young.

Axes are not to be used in pruning, but should be done by a saw.

Felling.

The age at which trees should be felled depends chiefly on the purpose for which they are grown.

Roadside and other isolated trees grown should not as a rule be felled until they die or are about to fall down from actual decay.

The best season for felling is cold weather. When the sap is down.

Method of Felling.

Trees should be cut as close to the ground as possible.

Average number of trees required to plant one acre at various distances apart.

Distance of lines in feet.	Distance between plants in feet.											
	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	11′	12′
1	*43,560*											
2	21,780	*10,890*										
3	14,520	7,260	*4,840*									
4	10,890	5,445	3,630	*2,723*								
5	8,712	4,356	2,904	2,178	*1,743*							
6	7,260	3,630	2,420	1,815	1,452	*1,210*						
7	6,223	3,112	2,075	1,556	1,745	1,037	*889*					
8	5,445	2,723	1,815	1,362	1,089	908	778	*681*				
9	4,840	2,420	1,614	1,210	979	807	691	605	*538*			
10	4,356	2,178	1,452	1,089	871	726	622	544	484	*430*		
11	3,960	1,980	1,320	990	792	660	566	495	440	396	*360*	
12	3,630	1,815	1,210	908	726	605	518	454	403	363	330	*303*

Average number of trees required to plant a line one mile long, at various distances apart.

Distance between plants.	No. of plants required.	Distance between plants.	No. of plants required.	Distance between plants.	No. of plants required.
10	528	17	311	24	220
11	480	18	293	25	211
12	440	19	273	26	203
13	406	20	264	27	196
14	377	21	251	28	189
15	352	22	240	29	182
16	330	23	230	30	176

Name of tree.	Number of seeds to the seer.	Name of tree.	Number of seeds to the seer.
Kikar ..	6,240	Sukhchein ..	468
Wilayati Kikar ..	10,336	Peach ..	100
Phulai ..	28,448	Amrud ..	14,968
Khair ..	25,344	Pear ..	42,708
Siris ..	7,424	Wild pear (Kaint) ..	900
Bel ..	1,048	Ritha ..	658
Mohwa ..	410	Tamarind ..	2,376
Kachnar ..	9,524	Bahera ..	316
Semal ..	25,248	Harrar ..	426
Chichra ..	636	Ber ..	1,850
Amaltas ..	6,432	Putanjan ..	1,606
Tun ..	3,65,504	Salhe ..	3,120
Lasura ..	16,820	Spruce ..	6,888
Shisham ..	23,070	Silver Fir ..	26,752
Loquat ..	910	Horse chestnut ..	54
Phalsa ..	2,450	Deodar ..	7,194
Dhamman ..	2,850	Cypress ..	1,56,800
Mango ..	42	Walnut ..	120
Bakain ..	1,280	Blue pine ..	15,264
Nim ..	10,850	Apricot ..	720
Champa ..	5,800	Plum ..	1,052
Khirni ..	5,456	Oak ..	410
Sohanjna ..	5,600	Maple ..	7,232
Aunla ..	52,528	Elm ..	39,092
Chil ..	6,976	Bamboo ..	28,160

Important Indian Trees and their Particulars.

Name of tree.	When and how sown.	Particulars.
Kikar or Babul ..	Sown in the rains or spring	The seed ripens in June and July. Before sowing it should be soaked for several days in cowdung and water. The young plants should be protected in winter.
Phulai ..	Sown in March or April ..	Grows in low hills generally on rocky and dry grounds.
Siris ..	Should be sown in nursery : Seedlings should be planted out at the end of the cold weather if irrigated, otherwise in rains.	Seed ripens in September and is hard but grows fast.

Name of tree.	When and how sown.	Particulars.
Bamboo ..	The seed should be sown in pots in March and watered regularly; may be planted in pits.	The whole clump that has come up in the pot should be planted into the pit without disturbing the earth round the roots. This can be done by breaking the pot.
Mohwa ..	It is propagated from seed.	Ripens from June to July. The seed should be soaked 10 to 12 days before sowing.
Kachnar ..	Easily grown from seed or from nursery.	Ripens in June or July. The seedlings require much light and will not spring up in shade.
Simbal ..	Propagated from seed and also from cuttings.	The seed ripens in April or May. If well watered the tree will grow fast. It requires a loose sandy soil.
Spanish Chestnut.	Seed sown in March or April in prepared nursery beds.	Seed ripens from August to September. The seed should be kept in dry earth until sown under to protect from attacks of vermins, seedling may be planted out during winter when 3 or 4 years old.
Tun ..	Propagated from seed sown in July, should be sown in nursery.	Ripens in June. The young seedlings require to be protected from sun and frost. It is handsome and shady.
Cadas or Diar and Kail.	Seed is sown in November, as soon.	Ripens in October and must be gathered at once just as it ripens, should be protected from frost. Watering is only required in May or June.
Orange, Santra and Narangi.	These stocks can be easily raised by sowing the seed of a well ripened lime or by planting cutting of sweet lime.	Requires plenty of manure and irrigation, varieties:— 1. Sweet lime. 2. Lemon. 3. Pomelo. 4. Sour lime.
Lasura ..	Propagated from seed, seedlings planted during rains.	Ripens in May or June. It is not a desirable tree for roadside.

Name of tree.	When and how sown.	Particulars.
Shisham, Sissu or Tahli.	Sowings should be made at beginning of the hot weather in irrigated land, and during winter rains on sailabas.	It requires much room and light to grow. Seed ripens in December or January. Young trees 10 to 12 ft. high can be planted successfully in the rains even in dry district.
Loquats ..	Can be sown from seed but grafting is better.	Is a native of China and Japan.
Jaman ..	Seed should be sown as soon as gathered in nurseries only, the seedling may be planted at the end of cold weather if irrigated, if not during the rains.	Ripens in June, July, several seeds are sown together and the healthiest seedlings kept, succeeds well on loam soil, requires waterings in the beginnings.
Bangantrice or Bor or Bargad	Propagated either from seed or from cuttings. Seedlings should be protected from sun and frost. Large cuttings 8 to 10 ft. high often succeed. Should be planted in May.	The seed ripens in April or May, should be planted at a distance of at least ½ mile, should be sown in pots in nursery beds broken bricks or charcoal mixed with the soil will assist the generation.
Fig or Angir ..	Easily raised from cuttings planted in a shady nursery bed.	The fruit ripens from May to August. Requires careful protection when fruit ripens.
Pipal ..	May be planted at end of cold weather or rains.	The seed ripens in April or May.
Phalsa ..	It may be grown from seed but the propagation of the best sorts is done by layering.	Seed ripens in May. The long shoots should be well pruned after the crop is gathered. The tree can be grown in irrigated garden.
Walnut tree or Akhrot.	The seed should be sown either when it first ripens or in January or February in prepared nursery beds of fine rich mould in distances 4½″ to 6″ apart and covered with 1″ or 2 ins. of soil.	The fruit ripens in September and should be stored in bag in a dry godown out of reach of vermin, rats, etc. The seed takes 6 months to grow and requires to be protected from monkeys. A surer way is to sow the seed in boxes, when the seedlings are one year old they should be transplanted in nursery. When 3 years old they can be transplanted during the rains.

Name of tree.	When and how sown.	Particulars.
Mangces	Seed is sown in August and seedlings planted in September. The best variety is obtained by grafting.	Seed ripens in June in Punjab. It will generate in 15 to 20 days. Requires waterings every 2 or 3 days. The young trees should be planted 20 ft. apart. Plantain trees, planted along-side the young mango trees while small, keep away white ants from attacking the trees and keep the roots moist.
Persian Lelal or Bakain.	The young seedlings may be planted out at the end of cold weather or during the rains. Seed is sown in February.	Ripens in January or February. This is a bad tree for avenues. It grows rapidly when young. Its roots are shallow and hence easily blown over.
Nim	Seed is sown in August and should be sown in well prepared nursery beds. The seedlings may be planted out with earth round the roots in December or in rains.	The seed ripens in July—August. Young plants should be protected from frost, require frequent waterings before rain
Khirni .	Grows easily from seed ..	Thrives well along rivers in sandy beds.
Mulberry or Tut.	Propagated from seed or from cuttings. Sown in June or July.	The seed ripens in April or May.
Plantain or Kela	Propagated by root suckers which spring up from the roots and planted out in a trench dug 3 feet deep and filled in with a mixture of ⅔ manure and ⅓ earth.	Plantains requires constant moisture and heavy manuring and are best grown along a trench leading from a well or canal.
Olive or Kau ..	Should be sown at end of cold weather in , well prepared nursery beds or pots in a soil mixed with charcoal and carefully watered. The seedlings should be planted in April if irrigated or during the	The seed ripens in August to November. The cultivated olive is propagated by taking the root suckers, which spring up near the pout-skin and planting them out, the good varieties being grafted on to these stems.

Name of tree.	When and how sown.	Particulars.
Date palm or Khajur.	Propagated from seed or from shoots. The young plants may be planted out when one year old or better when 2 years old.	Ripens in August, do not use wild palm for seed. It is best propagated by offsets as the seed always does not come out true.
Kail, Biar, Chair, Chil.	The seed is sown in November or December when ripe in trenches. Seedlings should be planted out during the rains when tall enough to hold their own.	Ripens in October or end of Autumn. To collect the seeds the ripening of cones must be watched and the cones gathered just before the scales open; slightly heated and the seeds picked out.
Jhand ..	May be propagated by transplanting root suckers or by seed, may be sown during the rains or in spring.	Ripens in June.
Almond or Badam	Almond trees may be raised from seed in the plains by sowing fresh almonds imported from Persian Gulf, sown in December or January.	Such trees do not, as a rule, seed in plains unless budded on to a peach or apricot stock.
Cherry or gilas ..	Tree may be propagated either by seed or by root suckers. The seedlings should be planted 12 ft. apart.	Ripens in June or July. Does not grow in plains.
Plum or Alucha ..	The grafts may be planted out in orchards when 1 to 3 years old. Cuttings of good varieties will also give excellent fruit.	Can be grown from seeds. Trees will not grow unless planted at about 20 ft. apart.
Peach or Aru ..	The tree requires careful manuring, irrigating and tending can be grown from seed but grafting is better.	The seed takes 6 months to generate. Trees should be planted 15 ft. apart.
Guava or Amrud ..	Propagated from seed during rains. Requires plenty of manure.	Superior varieties may easily be propagated by layering. When old the tree should be pruned.
Pomegranate or Anar.	Propagated from seed or cuttings.	Ripens in July to September.

Name of tree.	When and how sown.	Particulars.
Pear or Naspati	Propagated from seed or cuttings.	Fruit should be allowed to decay and then crushed and the seed and pulp sown together grows well in clayey, moist soils, trees should be planted about 24 ft. apart.
Apple or Seb ..	Propagated in the plains by root suckers or by budding	Should be planted about 24 ft. apart, will grow well in the hills.
Tamarisk or Farash.	Propagated easily from cuttings planted in January and February or in June and July.	Seed ripens in January, mix with sand when sowing.
Bahera ..	Propagated by seed, sown in April and seedlings planted in the rains.	It is difficult to rear the tree as an avenue tree.
Harar ..	Propagated from seed ..	Ripens from January to March.
Grape or Angur..	Propagated by cutting of well ripened wood, grown in nursery and planted in line 8 ft. apart.	Will bear fruit in 3 years. During the cold weather the ground should be well cultivated, the roots exposed for 15 days, and then the holes filled in with powerful manure, will require careful pruning during cold weather.
Ber ..	Propagated by seed, sown in rains, grafting is done. The grafts blossom in October, six or seven months after the operation and the fruit ripens in cold weather.	Ripens in May and June. The seed should be sown deep. It is liable to be scratched up by jackals. Best to raise the plants in nurseries. In early parts of February or end of cold weather an ordinary seedlings about 3 years old is cut down and allowed to throw out coppice shoots. The shoots from the stocks on which the superior variety it is wished to reproduce is grafted. This is done by ring grafting, whole bandaged up and covered over with clay in the usual way.

AGRICULTURAL DICTIONARY.

Serial No.	English.	Vernacular.	Serial No.	English.	Vernacular.
1	Apple	Seb.	30	Millet ..	Bajra.
2	Barley	Jau.	31	Maize ..	Makai.
3	Brinjal	Baingan.	32	Mango ..	Am.
4	Cocoanut ..	Nariyal.	33	Mulberry ..	Tut.
5	Cotton ..	Kapas.	34	Oats ..	Javar.
6	Chillies ..	Lal mirch.	35	Onions ..	Piaz.
7	Coriander ..	Dhania.	36	Orange ..	Narangi.
8	Citron ..	Galgal.	37	Pea ..	Mutter.
9	Cabbage ..	Band gobi.	38	Peach ..	Aru.
10	Carrot ..	Gajar	39	Plantain. ..	Kela.
11	Cucumbar ..	Khira.	40	Pomegranate ..	Anar.
12	Cauliflower ..	Phul gobi.	41	Pear ..	Nashpati.
13	Fig ..	Anjir	42	Pumpkin ..	Halwa Kadu.
14	French Bean ..	Frash Bean.	43	Potato ..	Alu.
15	Gram ..	Chana.	44	Potato sweet ..	Shakarkandi.
16	Green grain ..	Mung.	45	Rocket ..	Taramira.
17	Ginger ..	Adrak.	46	Rice ..	Chawal.
18	Garlic ..	Lassan	47	Radish ..	Muli.
19	Grapes ..	Angur.	48	Sugarcane ..	Ganna.
20	Guava ..	Amrud	49	Sesamum ..	Til.
21	Indian colza ..	Sarson.	50	Spinach ..	Palak.
22	Indian Rape ..	Toria.	51	Tea ..	Chah.
23	Lintel ..	Masur.			
			52	Turmeric ..	Haldi.
24	Linseed ..	Alsi.	53	Tobacco ..	Tambaku.
25	Lemon ..	Nibbu.			
26	Lady's finger ..	Bhindi Tori.	54	Tomato ..	Wilayeti Bangan.
			55	Turnips ..	Shalgham.
27	Luffar ..	Ghia Tori.			
28	Lotus root ..	Bhen.	56	Wheat ..	Gehun.
29	Mustard ..	Rai.	57	Walnut ..	Akhrot.

Principal Crops grown in Punjab.

Serial No.	Name of crop.	Time of sowing.	Time of harvesting.	Seed required per acre.	Yield per acre Irrigated.
				Srs.	lbs.
56	Wheat	15th Oct. to end of Nov.	April and May ..	20 to 30	1,020
5	Cotton (Desi) ..	April to 15th June ..	Sept. and Dec.	5 to 8	144
5	Cotton (Am.) ..	15th March to 15th May.	Sept. and Nov.	4 to 6	7
46	Rice ..	Sown in nursery in May or June and transplanted in July and August.	Sept. and Oct.	5 to 12	1,326
15	Gram ..	15th Sept. to end of Oct.	April and March	16 to 20	768
34	Jawar ..	Fodder March to Aug Grain, July to Aug.	May. to Oct. .. Oct. to Nov. ..	20 to 24 5 to 7 of canes.	 545
30	Bajra ..	15th June to end of July.	Oct. to 15th Nov.	2 to 2½	556
48	Sugarcane ..	March ..	Dec. to March ..	25 to 30 bundles of 100 canes each.	2,344
31	Maize ..	Fodder, March to Aug. Grain, June to end of July.	After 2 months of sowing. Nov.	12 6	 1,261
22	Toria ..	Early Sept. ..	15th Dec. to 15th Jan.	2 to 3	1,200
53	Tobacco ..	Sown in nursery in Oct. and transplanted in March.	June ..	¾ to 1	
2	Barley ..	Oct. to Nov. ..	April and May.	25 to 30	1,056
21	Sarson ..	15th Sept. to end of Nov.	March ..	2 to 3	
45	Taramira ..	15th Sept. to end of Nov.	15th March to .. 15th April.	2 to 3	

Table of Composition of some Indian Feeding Stuffs.

Name of stuff.	Moisture.	Ether extract.	Albuminoids.	Soluble carlo-hydrates.	Woody fibre.	Soluble mineral matter.	Sand and silica.	Total Nitrogen.	Albuminoid nitrogen.	Albuminoid nitrogen. Total	Food units.
	%	%	%	%	%	%	%	%	%		
Wheat (Lahore)	6·37	2·02	6·32	44·08	12·40	5·90	22·87	1·15	1·01	7·71	64·9
Rice (Basmati) Punjab.	11·28	·80	5·50	80·81	·23	·83	·55	1·04	·88	15·03	96·6
Gram (white)	10·36	4·22	22·81	57·48	1·93	3·15	·05	4.05	3·65	2·95	125·1
Jawar	12·04	3·13	8·19	73·44	1·37	1·64	·19	1·34	1·31	9·85	101·7
Bajra (Punjab)	10·08	4·93	11·12	71·07	·76	1·64	·40	1·86	1·78	7·41	111·2
Sugarcane (Lucknow).	31·85	1·03	1·01	37·76	21·56	2·23	4·56	·19	·16	39·73	42·9
Maize (dry) ..	10·04	2·52	9·17	37·76	25·25	8·44	6·82	1·95	1·51	4·75	67·0
Toria (Punjab)	6·81	10·28	27·19	37·08	9·85	7·10	1·69	4·66	4·35	2·23	130·8
Barley (Peshawar).	8·74	1·89	9·23	73·16	4·13	1·80	1·05	1·55	1·48	8·40	101·0
Sarson (P) (dried).	10·0	3·05	13·0	30·16	20·41	16·31	7·07	2·66	2·08	2·86	70·3
Taramira (Punjab).	9·44	8·83	36·0	28·48	6·86	5·52	4·87	5·76	..	1·30	140·6
Ginger ..	85·47	1·46	1·80	8·74	·95	1·58	0·0	·29	..	6·78	16·9
Til (Black), (Punjab).	5·57	52·27	17·94	13·26	3·87	6·58	·51	3·06	2·87	7·44	188·8
Mung (Punjab)	10·02	·93	22·94	58·94	3·38	3·74	·05	3·76	3·67	2·66	118·6
Urid (black), Punjab.	9·69	1·13	22·81	59·36	3·27	3·54	·20	3·75	3·65	2·72	119·2
Senji (Punjab).	84·40	·36	2·69	6·16	4·13	1·87	·39	5·15	·43	2·60	13·8
Cooked Food.											
Khichri .. (Rice and Dal)	11·68	1·05	13·44	31·36	·67	1·80	..	2·15	..	5·49	107·6
Common bread (Roti).	22·59	1·00	7·75	66·51	·66	1·49	..	1·24	..	8·88	88·4
Double bread (baked).	14·45	2·0	8·31	71·06	·09	2·09	..	1·33	..	9·10	96·8
Poori	18·0	8·27	9·31	62·49	·43	1·50	..	1·49	..	8·75	106·4
Kachauri ..	10·37	32·51	5·69	50·24	·10	1·09	..	·91	..	2·19	145·7

Composition of Milk and Butter.

	Buffalo's milk.	Cow's milk.	Goat's milk.	Butter.	English cow's milk.
Water ..	81-86	85-88	86	7 to 20	87
Fat ..	4.6 to 9·2	3·9 to 6·2	4·7 to 5·5	70 to 89	3·8
Sugar ..	·5	5	3·9	·2 to 2	4·6
Nitrogen ..	·6	·48	·54	·1	·64
Albuminoids ..	3·5 to 4	2·5 to 3·5	3·4	·2 to 2	4·0
Mineral matter ..	·8	·7	·6 to ·9	·1	·70

(*Handbook of Indian Agriculture.*)

Principal Vegetables.

Name of vegetables.	Moisture.	Ether extract.	Albuminoid.	Soluble carbohydrates.	Woody fibre.	Ashes.	Nitrogen.	Sand.	Phosphoric acid.
	%	Percentage on dry matter.					%		%
Palak ..	84	6.25	·75	63·88	9·12	20	·12	·75	1·5
Methi ..	77	4·8	16·21	56·11	11·51	11·37	2·61	·93	1·09
Karela ..	88·75	2·93	1·62	85·41	1·51	8·53	·26	·17	1·95
Brinjal ..	88·26	4·20	16·37	55·23	17·00	7·20	2·62	·70	..
Peas ..	77·0	1·0	26·31	57·61	9·56	5·52	4·21	..	..
French Beans ..	95·0	2·0	23·75	40·25	22·0	12·0	3·80	..	..
Bhindi ..	89·8	1·76	20·18	62·77	7·55	7·74	3·23	·19	..
Cabbage ..	92·0	3·0	19·5	61·78	8·87	7·25	3·12	·12	..
Cauliflower ..	90·0	3·30	36·4	41·3	10·5	8·50	5·8	·10	..
Muli ..	91·0	4·0	18·0	52·66	9·34	16·0	2·88	·33	1·32
Carrots ..	81·4	1·72	7·63	74·96	6·56	9·08	1·23	·48	·87
Sweet Potatoes ..	68·00	4·50	21·45	69·18	1·75	3·12	3·43	·12	..
Potatoes ..	80·66	·77	16·75	73·58	2·9[illegible]	5·97	2·67	..	..
Onions (red) ..	85·6	2·17	11·62	78·53	4·02	3·66	1·86	·630	..

Fruits.

Fruits are characterised by containing a large amount of water varying from 80 to 90%. The fruits generally contain edible and non-edible portion. It is the edible portion with which we are concerned. The remainder of the fruit usually consists of sugars, organic acids, starch gums, mineral matter and aromatic substances known as essential oils which usually give the characteristic flavour and aroma to the fruit. A small quantity of colouring matter is present also in many. Fruits contain only a very small quantity of Proteids or flesh forming material. The food constituents of the fruits are useful in supplying a part of the requirements of the human body but their importance is due in large portion to the presence of accessory food factors known as vitamins which seem to be essential in our food. The juice of fresh fruits is exceedingly valuable to children on account of these vitamins and fresh fruit should form part of our food if possible.

Principal Fruits.

Fruits.	*Non-edible portion.*		*Edible % or edible matter.*					Acidity, grains.
	Skin %.	Seed.	Juice, etc.	Moisture.	Reducing sugar.	Non-reducing sugar.	Total Sugar.	
Banana (Bombay) ..	20·3	..	79.7	72.0	4.58	10.49	15.07	..
Pomegranates (Kandhar)	16.71	13.55	69.74	.27	11.32	..	11.32	..
Grapes (Kandhari) ..	..	..	..	76.0	..	..	19.7	.64
Figs ..	..	..	..	75.0	50.0	4.0	54.0	..
Guavas (with seed removed)		..	..	78.0	10.0	12.0	22.0	..
Oranges (Nagpur) ..	Total	=43.0	57.0	..	4.0	3.5	7.5	..
			Acidity=·85 grains of citric acid ..					
				=.62 grains of sulphuric acid				
Mangoes (on pulp) ..				81.3	14.46	33.78	58.22	·20

Conversion Table for converting Kanal and Marlas into acres and decimals, when the Karm =5 5 ft.

1 acre = 8 Kanals 0 Marla.
2 acres = 16 ,, 0 ,,
3 acres = 24 ,, 0 ,,
4 acres = 32 ,, 0 ,,

Kanals.	Marlas.																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	0	·01	·01	·02	·03	·03	04	04	·05	·06	·06	·07	·08	·08	·09	·09	·10	·11	·11	·12
1	·13	·13	·14	·14	15	·15	·16	17	·18	·18	·19	·19	·20	·21	·21	·22	·23	·23	·24	·24
2	·25	·26	·26	·27	·28	·28	29	·29	·30	·31	·31	·32	·33	·33	·34	·34	·35	·36	·36	·37
3	·38	·38	·39	·39	·40	·41	·41	42	·43	·43	44	·44	·45	·46	46	·47	·48	·48	·49	·49
4	·50	·51	·51	·52	·53	·53	·54	·54	·55	·56	57	·57	·58	·58	·59	·59	·60	·61	·61	·62
5	·63	·63	·64	·64	·65	·66	·66	·67	·68	·68	·69	·69	·70	·71	·71	·72	·73	·73	·74	·74
6	·75	·76	·76	·77	·78	·78	·79	·79	·80	·81	·81	·82	·83	·83	·84	·84	·85	·86	·86	·87
7	·88	·88	·89	·89	·90	·91	·91	·92	·93	·93	·94	·94	·95	·96	·96	·97	·98	·98	·99	·99
8	1·00																			

Conversion Table for converting Kanals and Marlas into Acres and Decimals, when the Karm =5 ft.

1 acre	=	9	Kanals	13 Marlas.
2 acres	=	19	,,	6 ,,
3 acres	=	28	,,	19 ,,
4 acres	=	38	,,	12 ,,

Kanals.	Marlas.																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	0	·01	·01	·02	·02	·03	·03	·04	·04	·05	·05	·06	·06	·07	·07	·08	·08	·09	·09	·10
1	·10	·11	·11	·12	·12	·13	·13	·14	·14	·15	·15	·16	·16	·17	·17	·18	·18	·19	·19	·20
2	·21	·21	·22	·22	·23	·23	·24	·24	·25	·25	·26	·26	·27	·27	·28	·28	·29	·29	·30	·30
3	·31	·32	·32	·33	·33	·34	·34	·35	·35	·36	·36	·37	·37	·38	·38	·39	·39	·40	·40	·41
4	·41	·42	·42	·43	·43	·44	·44	·45	·45	·46	·46	·47	·48	·48	·49	·49	·50	·50	·51	·51
5	·52	·52	·53	·53	·54	·54	·55	·55	·56	·56	·57	·57	·58	·58	·59	·59	·60	·60	·61	·61
6	·62	·63	·63	·64	·64	·65	·65	·66	·66	·67	·67	·68	·68	·69	·69	·70	·70	·71	·71	·72
7	·72	·73	·73	·74	·74	·75	·75	·76	·76	·77	·77	·78	·78	·79	·79	·80	·80	·81	·81	·82
8	·83	·83	·84	·84	·85	·85	·86	·86	·87	·87	·88	·88	·89	·89	·90	·90	·91	·91	·92	·92
9	·93	·93	·94	·95	·95	·96	·96	·97	·97	·98	·98	·99	1·00	..	..	..	..	..	..	..

Statement comparing the area under various crops in India in thouasnd acres in 1923-24.

Crop	Area	Crop	Area	Crop	Area
Rice	.. 77,200	Linseed	.. 2,645	Cotton	.. 15,583
Wheat	.. 24,294	Rape and Mustard seed	.. 3,655	Jute	.. 2,329
Other food grains	.. 95,505	Other oil seeds	.. 7,962	Other pulses	.. 703
Fodder crops	.. 8,764	Tobacco	.. 1,025	Coffee, Indigo and opium	... 415
Sugarcane	.. 3,045	Tea	.. 713		

Grand total area cultivated in 1923-24=243,640 thousand acres.

{ *Memoranda for the Royal Commission on Agriculture.*

TECHNICAL DICTIONARY.

FROM ENGLISH TO HINDUSTANI.

NAME OF BUILDINGS.

English.	Hindustani.
Burial ground or Cemetery	..Qabristan.
Bungalow	..Bangla.
Cantonment	..Chhaoni.
Chamber	..Kothri.
Church	..Girja-ghar.
City	..Shahr.
Civil Dispensary	Sarkari Dawakhana.
College	..Madarsa.
Drain	..Mori.
Flat-roofed house	Kothi.
Fort	..Qila.
Godown	..Godam.
Hospital	..Bara Dawakhana.
House	..Ghar.
Jail	..Kaidkhana.
Laboratory	..Karkhana.
Mosque	..Musjid.
Office	..Daftar.
Police Station	..Thana.
Palace	..Mahal.
Printing Office	..Chhapakhana.
Post Office	..Dakkhana.
Prison	..Kaidkhana.
School	..Maktab.
Sewer	..Badar-rau, nali.
Shop	..Dukan.
Staging house	..Chauki.
Stable	..Astabal.
Temple	..Mandar.
Treasury (Local)	Tahsil.
Tower	..Burj.
Tomb.	..Qabr.
Town	..Qasba.
University	..Dar-ul-alum.
Village	..Gaon.
Workshop	..Karkhana.

NAME OF WORK PEOPLE, ARTIZANS, ETC.

English.	Hindustani.
Artizan	..Karigar.
Banker	..Mahajan.
Blacksmith	..Luhar.
Bricklayer	..Raj.
Book Binder	..Jildsaz.
Carpenter	..Barhai.
Carter	..Gariban.
Cloth Merchant	..Bazzaz.
Cobbler	..Mochi.
Corn dealer	..Baniya.
Digger	..Beldar.
Dyer	..Rangrez.
Electrician	..Bijli ka kam karnewala.
Goldsmith	..Sunar.
Jeweller	..Jauhri.
Labourer	..Kuli.
Messenger	..Chaprasi.
Mason	..Raj.
Mat-maker	..Chataiwala.
Merchant	..Saudagar.
Printer	..Chhapaiwala.
Painter	..Rangsaz.
Potter	..Ghumar.
Shoe-maker	..Chamar.
Surveyor	..Paimaish kuninda.
Thatcher	..Chhaparband.
Tent keeper	..Khalasi.
Tailor	..Durzi.
Tin man	..Kalaigar.
Thatcher	..Gharami.
Water carrier	..Bhahishti.
Well sinker	..Chah-kan.
Writer	..Moharrir.
Weaver	..Julaha.

EARTHWORK, Etc.

English.	Hindustani.
Axle	..Dhura.
Bucket (Leather)	Charsa.
Burden	..Bojh.
Barrow wheel	..Hath Gari.
Basket	..Tokri.
Barrow hand	..Manjhi.
Cart	..Gari.
Clay	..Mitti.
Coarse broad tape	Niwar.
Dibble (grass cutter's)	..Khurpa.
Excavator	..Beldar.
Excavation	..Khodai.
Ground square	..Gunia.
Gang	..Madad.
Hoe (used in well sinking)	..Jham.
Helve, Handle	..Dasta.
Measure	..Paimana.
Measuring Rod	..Gaz.
Pile	..Kari.
Peg	..Khunti.
Pickaxe	..Genti.
Pile engine	..Machak.
Rammer	..Durmat.
Reaping hook	..Daranti.
Sickle	..Daranti.
Slope	..Dhal.
Trip	..Khep.
Tracing	..Dagbel.
Tire	..Ahal.
Yoke	..Jua.
Well	..Kuan.
Wheel	..Pahiya.

BRICK MAKING.

English.	Hindustani.
Ashes	..Rakh.
Brick (sundried)	..Kachchi Int.
Brick	..Int.
Brick (half burnt)	Pilli Int.
Brick-bat	..Rora.
Brick (vitrified)	..Jhanwan.
Cord	..Dori.
Clod	..Dhela.
Clamp (native)	..Pazawa.
Cowdung	..Upla.
Distorted	..Tehra.
Dust	..Khak.
Enclosed kiln	..Bhattha.
Earth	..Mitti.
Hod (for carrying mortar)	..Katahra.
Mould	..Sancha.
Manure	..Khad.
Mud, Mire	..Kichar.
Mud mortar	..Gara.
Potter's wheel	..Chak.
Reservoir	..Hauz.
Rope	..Rassa.
Sand	..Ret.
Sandy	..Retla.
Sieve	..Chalna.
Spade	..Belcha.
Spade (native)	..Phaura.

BUILDINGS.

English.	Hindustani.
Arch	..Dat, Mehrab.
Albaster	..Sang Marmar.
Brickwork in mortar	..Chunai.
Bond, to preserve	Darz bachana.
Beam	..Shahtir.
Brick-on-edge flooring	..Kharanja.
Buttress	..Pushta.
Brick pointing	..Tip.
Cornice	..Kangni.
Corner	..Kona, Gosha.

BUILDINGS—concld.

English.	Hindustani.	English.	Hindustani.
Centring	..Dhola, Qalib.	Mason's Hammer	Hathora.
Dome	..Gumbaz.	Plastering (Lime)	Astarkari.
Flooring	..Farsh.	Plastering (mud)	Lipai.
Foundation	..Bunyad.	Pillar	..Pil-paya.
Flat tile	..Khaprel.	Plummet	..Sahal.
Gravel	..Bajri.	Pounded bricks	..Surkhi.
Level	..Hamwar.	Roof	..Chhat.
Ladder	..Sirhi.	Rafter	..Kari.
Layer	..Radda.	Scaffolding	..Par.
Lime	..Chuna.	Stone	..Paththar.
Lime (quick)	..Kachcha chuna.	Terraced floor	..Pakka farsh.
Lime (slackened)	Bujha hua chuna.	Terraced roof	..Pakki chhat.
Lime burner	..Chuna-puz.	Tube	..Nal.
Lime kiln	..Chuna ki bhatti.	Thread	..Sut.
Limestone	..Kankar.	Truss	..Kainchi.
Lime for white-wash	..Safedi.	Trowel	..Karni.
Lime mill	..Chuna ki chakki.	Tiled Roof	..Khaprel ki chhat
Measuring tape	..Fita.	Verandah	..Baramda.
		Water mill	..Pan chaki.

BRIDGE BUILDING.

English.	Hindustani.	English.	Hindustani.
Abutment	..Paya-beruni.	Inverted arch	..Dat ulti.
Afflux	..Bahao.	Joint	..Jor.
Batter	..Baqaida salami.	Keystone	..Dat ki chabi.
Bonding	..Band.	Pier	..Paya andruni.
Bridge	..Pul.	Parapet	..Munder.
Bottom	..Tali.	Retaining wall	..Dewar-i-pushta.
Breast wall	..Diwar-i-pushta.	Road	..Sarak.
Bank, edge	..Kinara.	River	..Darya.
Cut water	..Abtarash.	Splay	..Kham.
Crown of arch	..Ras-i-mehrab.	Springing	..Shuru Kaus.
Curtain wall	..Samne ki diwar.	Span of arch	..Wusat Dat.
Haunches	..Atraf.	Wing wall	..Dewar-i-Bazu.

CARPENTRY.

English.	Hindustani.	English.	Hindustani.
Adze	..Basula.	Chisel	..Chaursi.
Auger	..Barma.	Circular saw	..Gol ara.
Box	..Sanduq.	Compass	..Purkar.
Barrel	..Pipa.	Curb	..Nim chak.
Block or pulley	..Ghirni.	Door frame	..Chaukat.
Brad-awl	..Min.	Door	..Kiwar.

CARPENTRY—concld.

English.	Hindustani.	English.	Hindustani.
Door bolt	..Billi.	Paste	..Lei.
File	..Reti.	Pile driver	..Machak.
Felling axe	..Kulhari.	Sawdust	..Burada.
Glue	..Saresh.	Screw driver	..Pechkash.
Gum	..Gond.	Sliding bolt	..Chitkani.
Hand saw	..Ari.	Straight edge	..Gaz.
Hinge	..Qabza.	Tools	..Auzar.
Key	..Chabi.	Tack	..Baranji.
Lock	..Tala.	Tenon	..Chul.
Nail	..Kil.	Table	..Mez.
Panel	..Dolha.	Windlass	..Charkhi.
Plane	..Randa.	Window	..Khirki.
Press	..Shakanja.		

THATCHING.

English.	Hindustani.	English.	Hindustani.
Bamboo	..Bans.	Munj string	..Ban.
Bundle	..Pula.	Mat screen	..Jhanp.
Cotton rope	..Sut ki rassi.	Ridge pole	..Bareri.
Flax	..Sun.	Reed	..Sarkanda.
Grass rope	..Munj.	Shutter	..Pardah.

METALS.

English.	Hindustani.	English.	Hindustani.
Bell metal	..Azdhat.	Iron rod	..Loha gol.
Brass	..Pital.	Iron wrought	..Ghara hua loha.
Copper	..Tamba.	Iron cast	..Dhala hua loha.
Gold	..Sona.	Lead	..Sisa, Sikka.
Iron	..Loha.	Metal	..Dhat.
Iron wire	..Lohe ki tar.	Quicksilver	..Para.
Iron sheet	..Lohe ki chadar.	Steel	..Aspat.
Iron flat	..Loha chapta.	Silver	..Chandi.
Iron bar	..Loha chaukor.	Tin	..Qalai.
Iron pig	..Loha sari.	Zinc	..Jast.
Iron hoop	..Loha kundli.		

PAINTERS' WORK.

English.	Hindustani.	English.	Hindustani.
Amber	..Kah-ruba.	Arsenic	..Sankhia.
Alkali	..Khar.	Ammoniac	..Nushadir.
Acid acetic	..Sirka ka tezab.	Borax	..Sohaga.
Acid sulphuric	..Gandhak ka tezab.	Beeswax	..Mom.
Acid nitric	..Shora ka tezab.	Bitumen	..Nafta.
Acid muriatic	..Namak ka tezab.		

PAINTERS' WORK—concld.

English.	Hindustani.	English.	Hindustani.
Benzoin	..Loban.	Oil sweet	..Til ka tel.
Blue vitriol	..Nila Tutia.	Oil mustard	..Tel sarson ka.
Bole Earth	..Multani Mitti.	Oil of turpentine	Tarpin ka tel.
Cocoanut oil	..Tel Nariyal ka.	Oil Linseed	..Alsi ka Tel.
Copal gum	..Sundras.	Orpiment	..Hartal.
Camphor	..Kafur.	Pumice Stone	..Jham.
Chalk, whiting	..Khariya mitti.	Rosin	..Ral.
Emery	..Kuranj.	Red Lead	..Sandur.
Gamboge	..Osara Rewand.	Red Ochre	..Geru.
Glass phial	..Shisha.	Shellac	..Lak Chapra.
Isinglass	..Abrak.	Stone (for grinding colour on)	Sil.
Indigo	..Nil.	Sugar of lead	..Hil.
Litharge	..Murdar sang.	Sulphur	..Gandhak.
Lead	..Sisa, Sikka.	Turpentine	..Gandah berozah.
Lamp black	..Kajal.	White Lead	..Sufeda.
Naptha	..Nafta.	Yellow Ochre	..Pili mitti.
Oil	..Tel.		

BLACKSMITHS' WORK.

English.	Hindustani.	English.	Hindustani.
Anvil	..Sandan.	Red hot	..Tao.
Augar	..Barma.	Rake	..Jeli.
Blacksmith	..Lohar.	Solder	..Rang.
Bellows	..Dhaunkni.	Screw bolt	..Qulaba.
Charcoal	..Koila.	Scissors	..Qenchi.
Cast (To)	..Dhalna.	Sledge hammer	..Ghan.
Fireplace	..Angithi.	Tongs	..Chimta.
File, Rash	..Sohan.	Wedge	..Pachchar, Phana.
Heat (To)	..Tao Dena.	Washer	..Patti.
Leather	..Chamra.	Wire drawer	..Tar Kash.
Nut	..Dhibri.	Vice	..Bank.
Nut Key	..Dhibri Kash.	Vice, large	..Mez ki bank.
Pinchers	..Chimta.	Vice, hand	..Hath ki bank.
Punch	..Sunba.		

SURVEYING.

English.	Hindustani.	English.	Hindustani.
Arrow	..Sua	Map	..Naqsha.
Bench mark	..Matam.	Plot (To)	..Naqsha banana.
Contouring	..Tilon ka dhal.	Peg	..Khunti.
Chain	..Jarib.	Survey	..Pamaish.
Datum line	..Farzi khat.	Staff	..Gaz.
Flag	..Jhandi.	Tape	..Fita.
Levelling	..Hamvari.	Tripod	..Tipai.
Measure	..Nap.	Telescope	..Durbin.

GENERAL.

English.	Hindustani.	English.	Hindustani.
Acacia tree	..Kikar.	Efflorescence of salt on walls	..Noni.
Agate	..Sang-Sulaimani.	Electricity	..Bijli.
Alloy (of metals)	Bhart.	Elevation	..Unchai.
Almanac	..Patra.	Embanking	..Bhrai.
Alum	..Phitkari.	Enclosure	..Ihata.
Amethyst	..Yakut.	Estimate	..Takhmina.
Angle	..Kona, Gosha.	Expenses	..Kharch.
Angle, right	..Qaima Zavia.	Extension	..Khichao.
Angular	..Konedar.	Faggot	..Bojha.
Aniseed	..Saunf.	Ferry	..Ghat.
Ant, white	..Dimak.	Finger	..Ungli.
Arc	..Kaus.	Fir	..Sanaubar.
Architecture	..Ilm-i-tamir.	Flood	..Sailab.
Area	..Raqba.	Grass	..Ghas.
Bastion	..Burj	Grease	..Charbi.
Bend	..Mor, kham.	Gun Powder	..Barud.
Bracket	..Khutut Wahdani.	Horsedung	..Lid.
Bridle	..Bag.	Inclination	..Salami.
Blotting paper	..Sayai Chus.	Irrigation	..Abpashi.
Camel	..Unt.	Lithography	..Pathar ki chhapai.
Camp	..Parao.	List	..Fehrist.
Canal	..Nahr.	Marble	..Sang-i-marmar.
Cellar	..Teh-khana.	Marsh	..Daldal.
Chain	..Zanjir.	Money (bullion)	..Naqad.
Chimney	..Dud-kash.	North	..Shamal.
Cinnabar	..Shingraf.	North Star	..Qutabi-Sitara.
Circumference	..Girda.	Notch	..Danti.
Circle	..Daira.	Newspaper	.Akhbar.
Clock	..Ghari.	Palace	.Mahal.
Construct	..Banana.	Palate	.Talu.
Contractor	..Thekedar.	Parallel	.Mutawazi.
Concrete	..Rori.	Perennial	.Bara-masiya.
Coping of wall	..Munderi.	Perpendicular	.Khara.
Cube	..Mukab.	Persian wheel	.Harat, Rahat.
Cheap	..Sasta.	Plough	.Hal.
Depth	..Gehrai.	Porch	.Osara.
Deep	..Gehra.	Portfolio	.Juzdan.
Detail	..Tafsil.	Pump	.Nal.
Diamond (Glaziers)	..Kalam hire ki.	Pay (to)	.Ada Karna.
Dictionary	..Lughat.	Price	.Qimat.
Doctor	..Hakim.	Pay	.Talab-Tankhah.
Dry rot	..Ghun.	Pen	.Qalam.
Dear	..Mehnga.	Paper	.Kagaz.
Draft (cheque)	..Hund	Quarry	.Pathar ki Kan.

GENERAL—concld.

English.	Hindustani.	English.	Hindustani
Question	..Sawal.	Street	..Kucha.
Quotient	..Hasil.	Tailor	..Darzi.
Remainder	..Baqi.	Tallow	..Charbi.
Reservoir	..Hauz.	Timber	..Lakri.
Rice	..Chawal.	Triangle	..Musallas.
Saltpetre	..Shora.	Tunnel	..Surang.
Sand	..Ret.	Vernacular	..Desi.
Sand Coarse	..Bajri.	Vinegar	..Sirka.
Sandpaper	..Regmal.	Vitriol, white	..Hira Kasis.
Scales	..Tarazu.	Wagon	..Gari.
Semi-circle	..Nisaf daira.	Whitewash	..Sufedi.
Sewer	..Badarrau.	Weight	..Wazan.
Stable	..Astabal.	Yeast	..Khamir.
Stream	..Dhar.	Zigzag	..Tehra-banka.

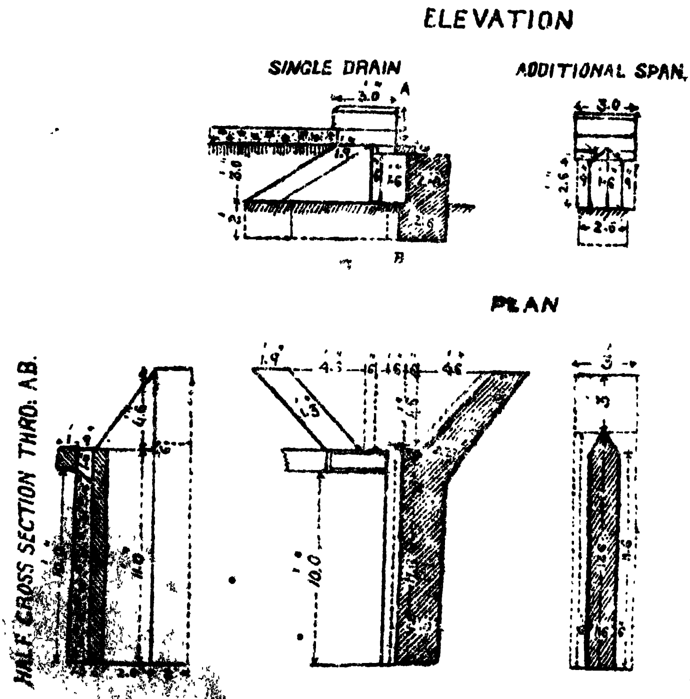
PART II.

DRAWINGS.

Printed at Washington Press, Lahore.

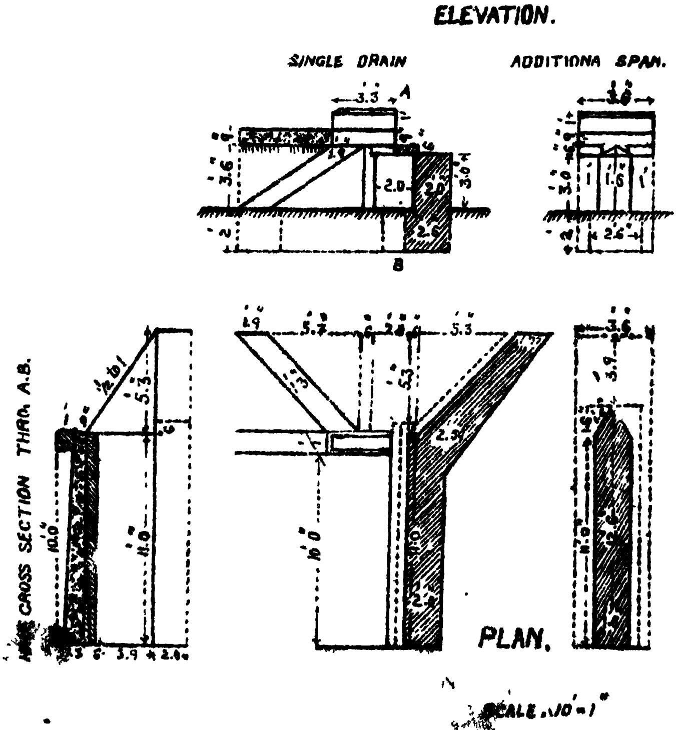
ROAD BRIDGES

1½ FOOT SLAB DRAIN

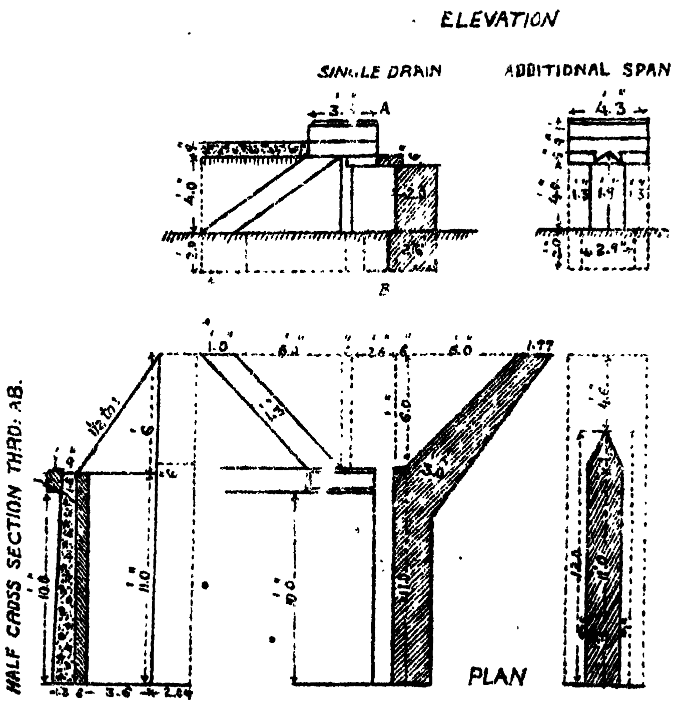


Scale, 10'=1"

2 FEET SLAB DRAIN



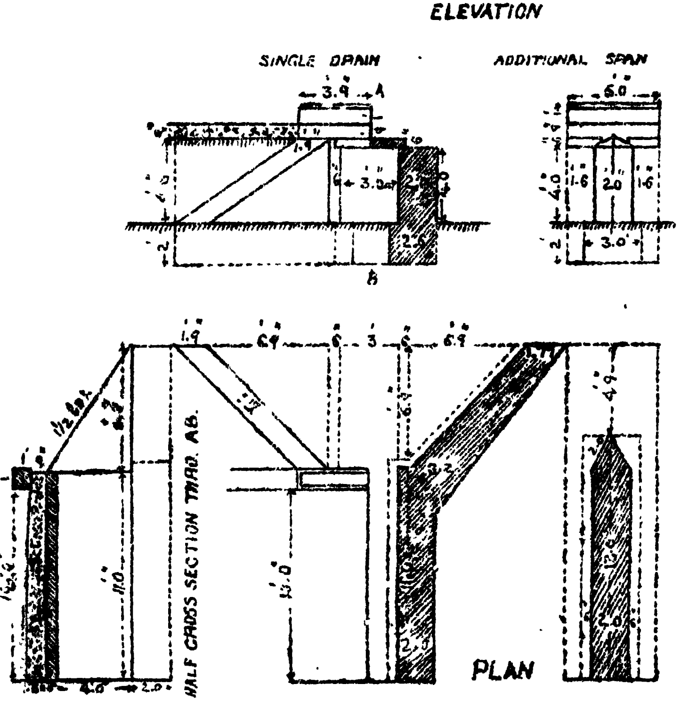
2½ FEET SLAB DRAIN



SCALE, 10' = 1"

3 FEET SLAB DRAIN

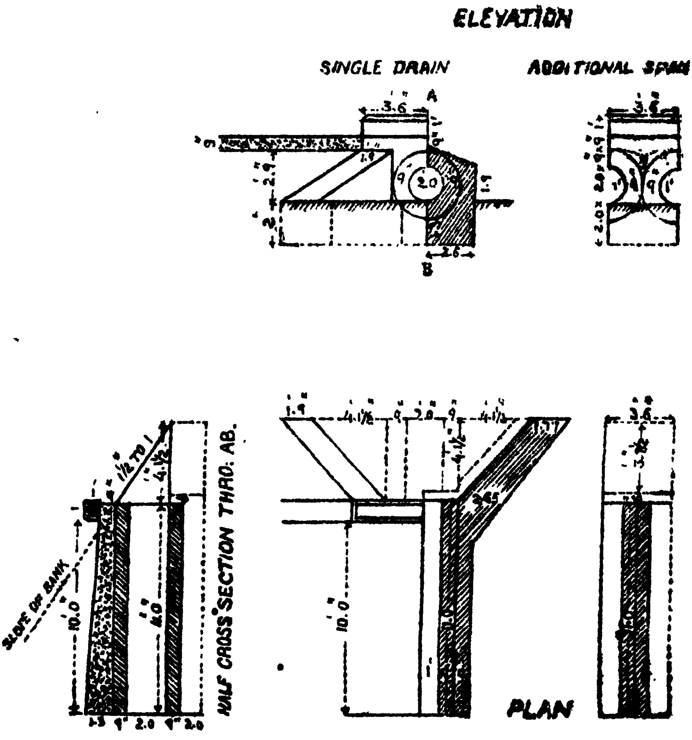
SCALE, 10 = 1".



Note. No outwater on down-stream side.

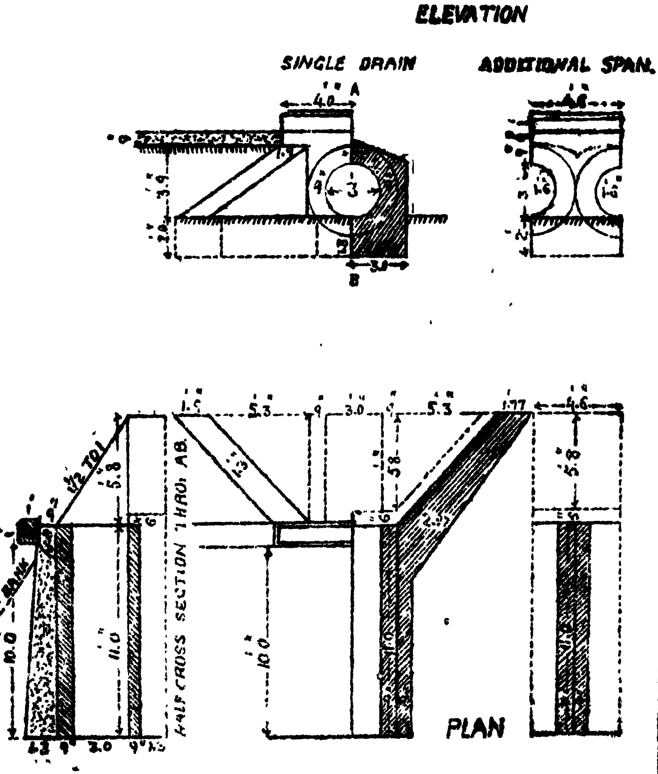
2 FEET BARREL DRAIN

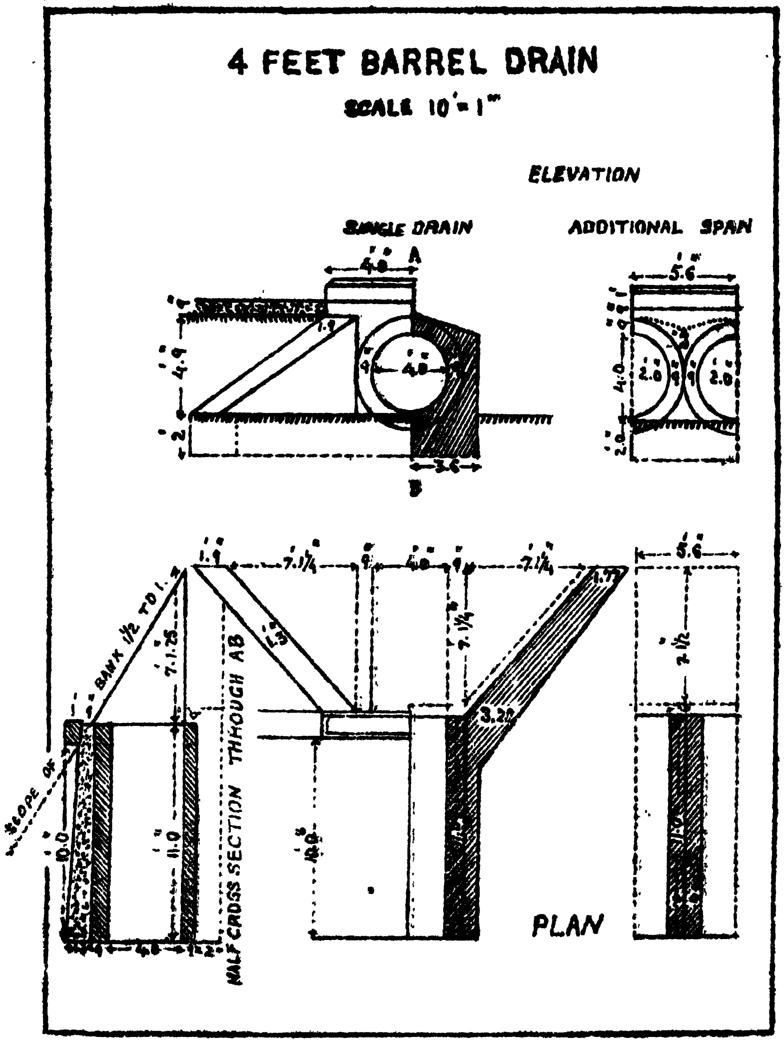
SCALE, 10' = 1"



3 FEET BARREL DRAIN

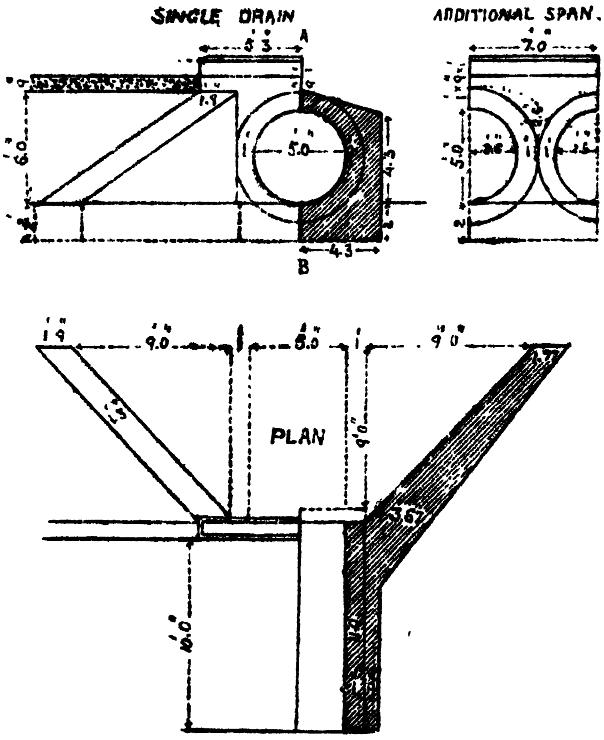
SCALE, 10' = 1"




4 FEET BARREL DRAIN
SCALE 10' = 1"
ELEVATION
SINGLE DRAIN
ADDITIONAL SPAN
PLAN
SLOPE OF
BANK 1½ TO 1
HALF CROSS SECTION THROUGH AB

5 FEET BARREL DRAIN

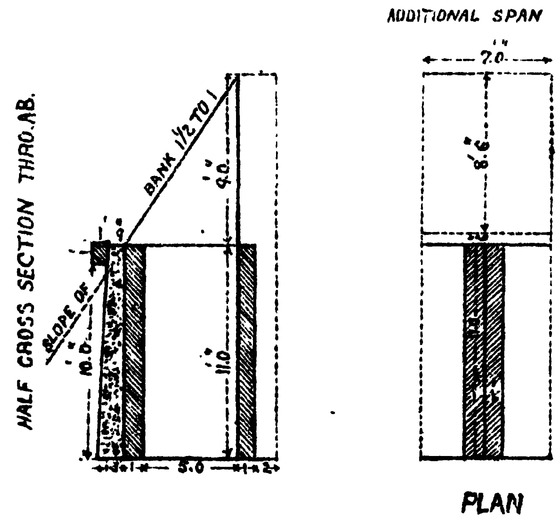
ELEVATION.



SCALE 10' = 1"

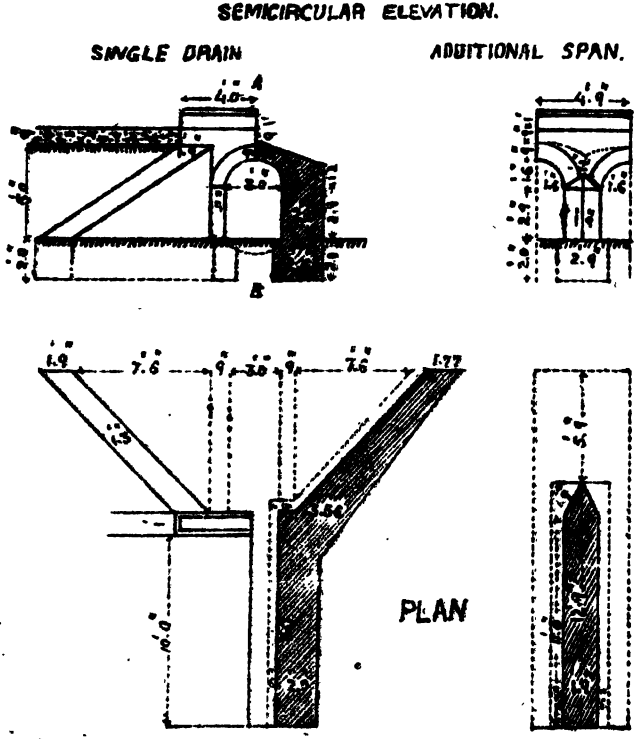
5 FEET BARREL DRAIN (CONTINUED)

SCALE 10' = 1".



3 FEET CULVERT

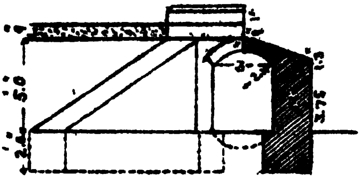
SCALE 10'=1"



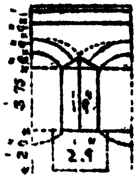
3 FEET CULVERT (CONTINUED)

SEGMENTAL ELEVATION

SINGLE DRAIN

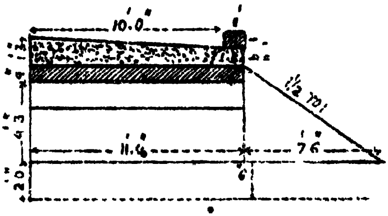


ADDITIONAL SPAN

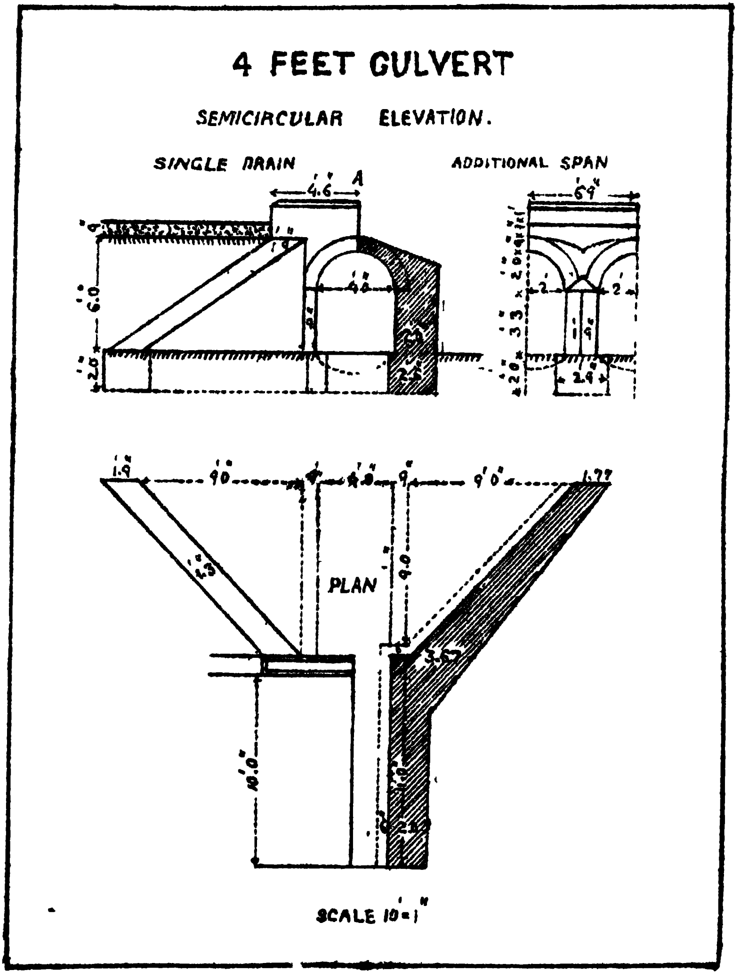


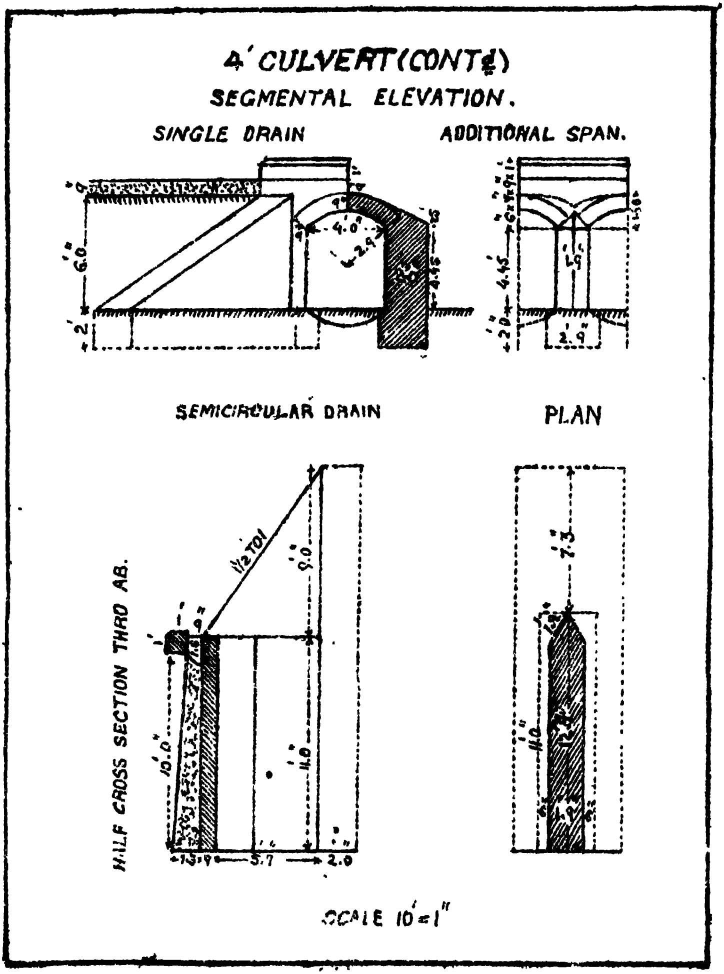
SEMICIRCULAR DRAIN

HALF CROSS SECTION THROUGH AB.

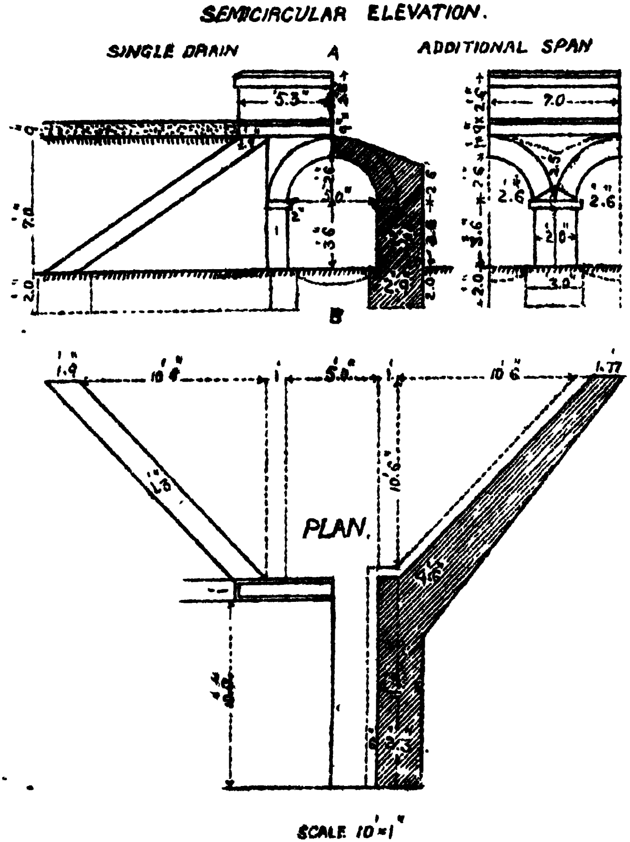


SCALE 10' = 1"


4 FEET CULVERT
SEMICIRCULAR ELEVATION.
SINGLE DRAIN
ADDITIONAL SPAN
A
PLAN
SCALE 10'=1"

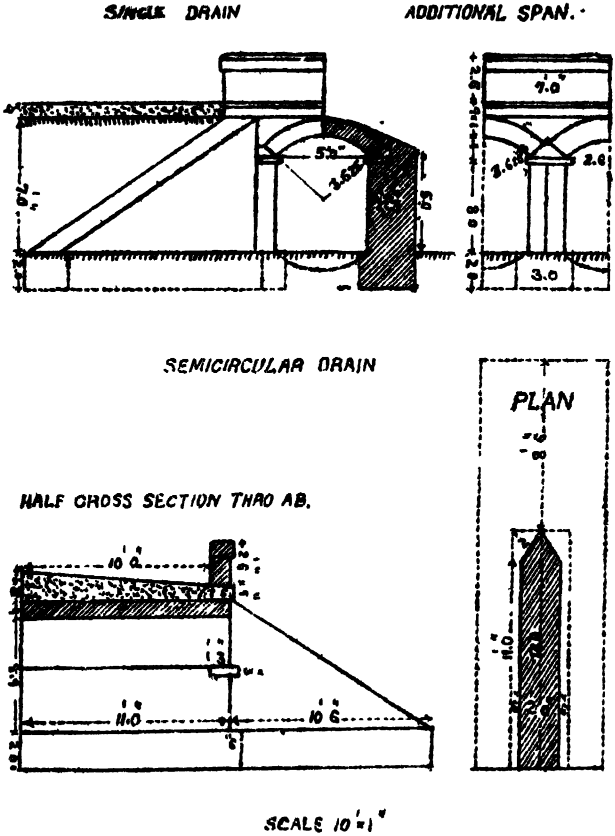

4' CULVERT (CONTd)
SEGMENTAL ELEVATION.
SINGLE DRAIN
ADDITIONAL SPAN.
SEMICIRCULAR DRAIN
PLAN
HALF CROSS SECTION THRO AB.
1½ TO 1
SCALE 10' = 1"

5 FEET CULVERT



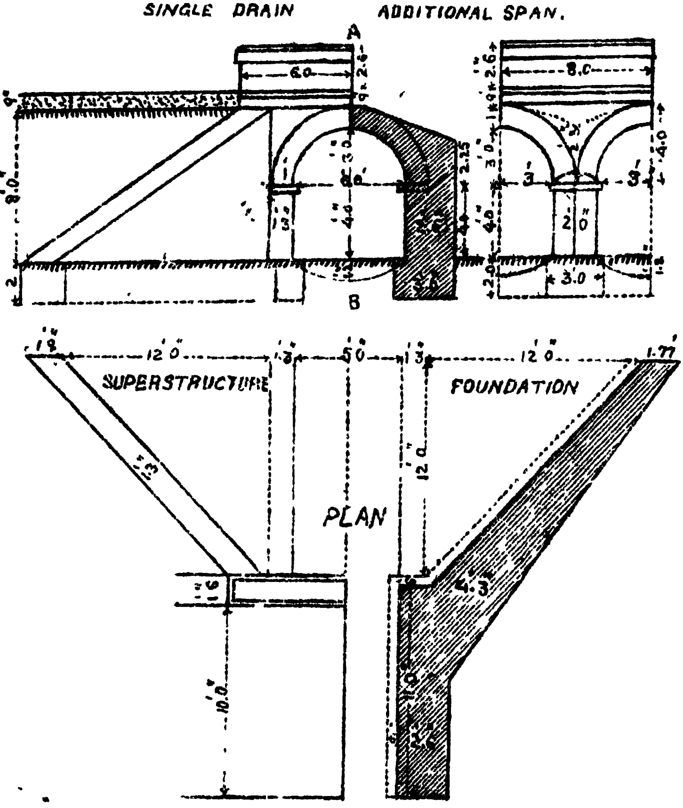
5FEET CULVERT (CONTINUED)

SEGMENTAL ELEVATION



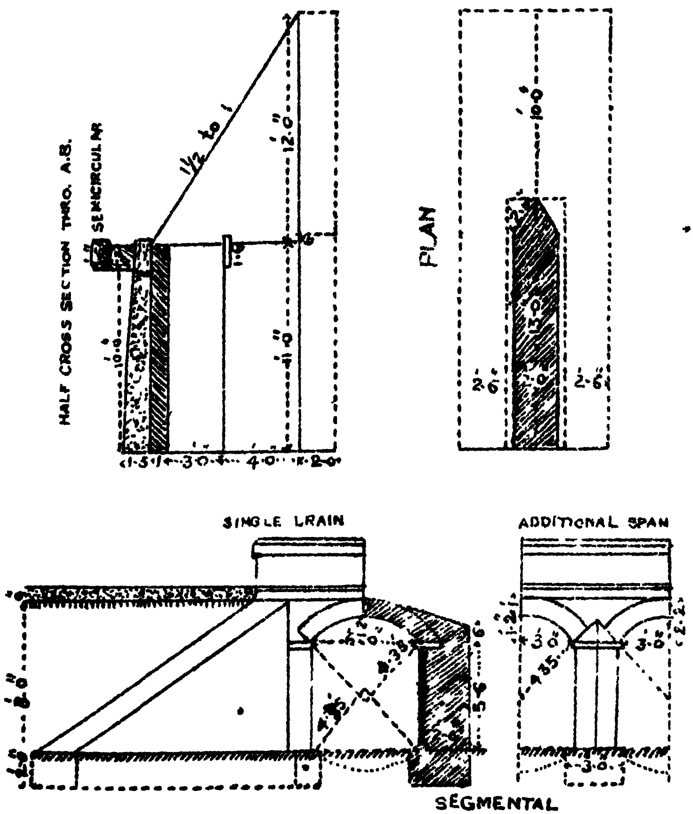
6 FEET OULVERT

SEMICIRCULAR ELEVATION.

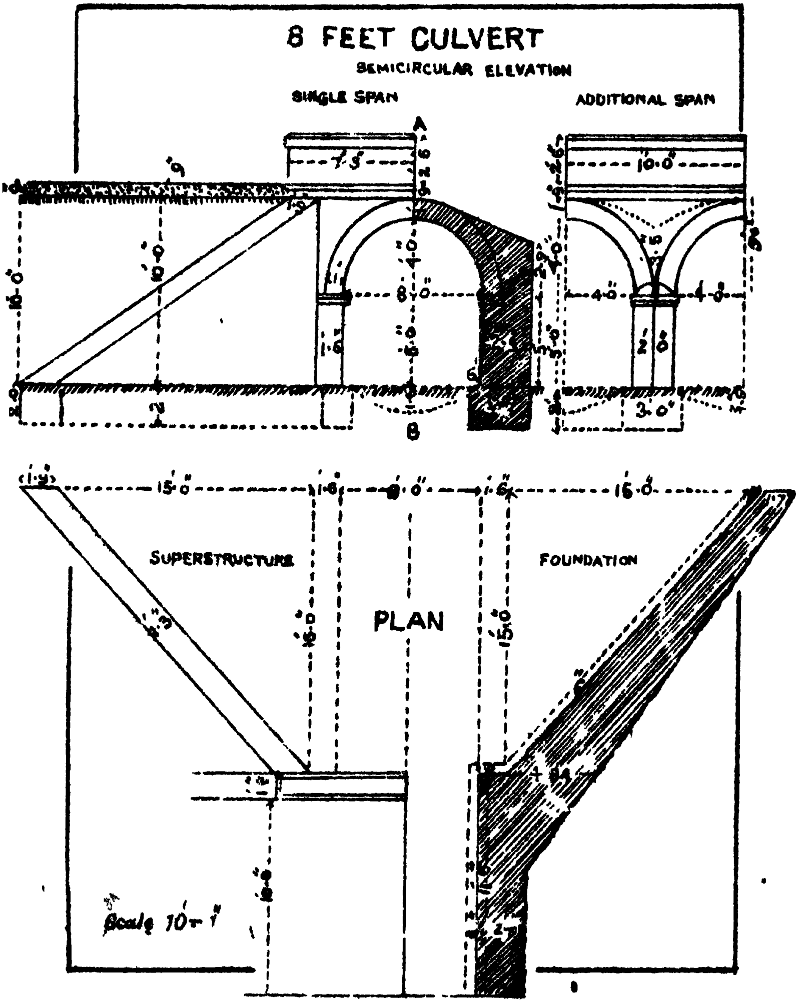


SCAL 10'=1"

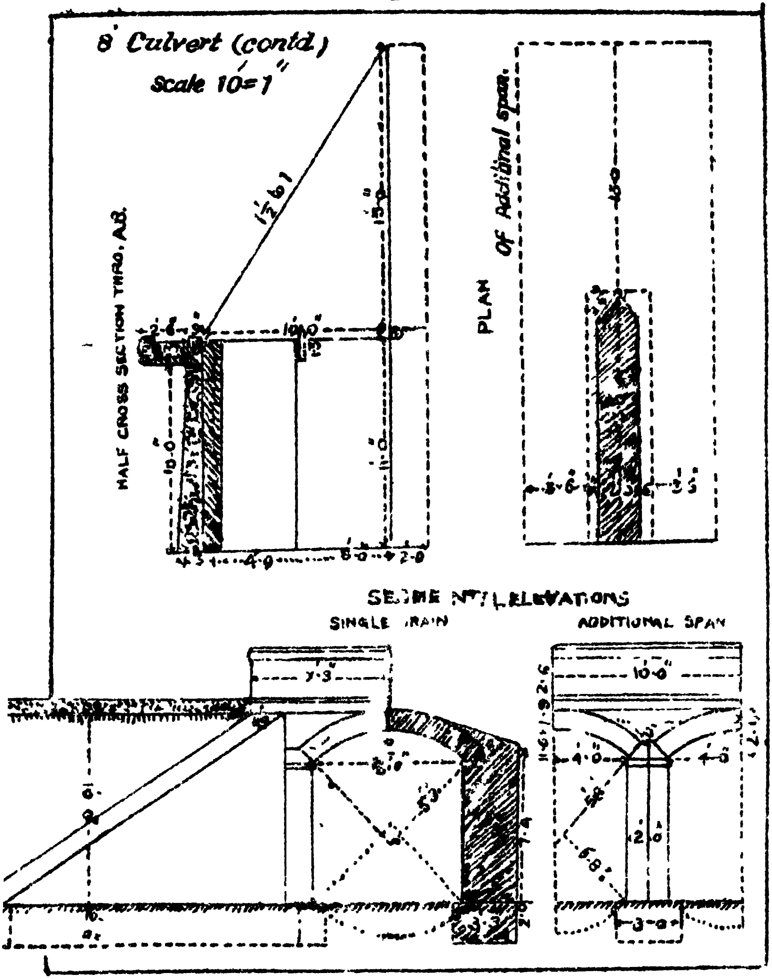
6' Culvert (Contd)



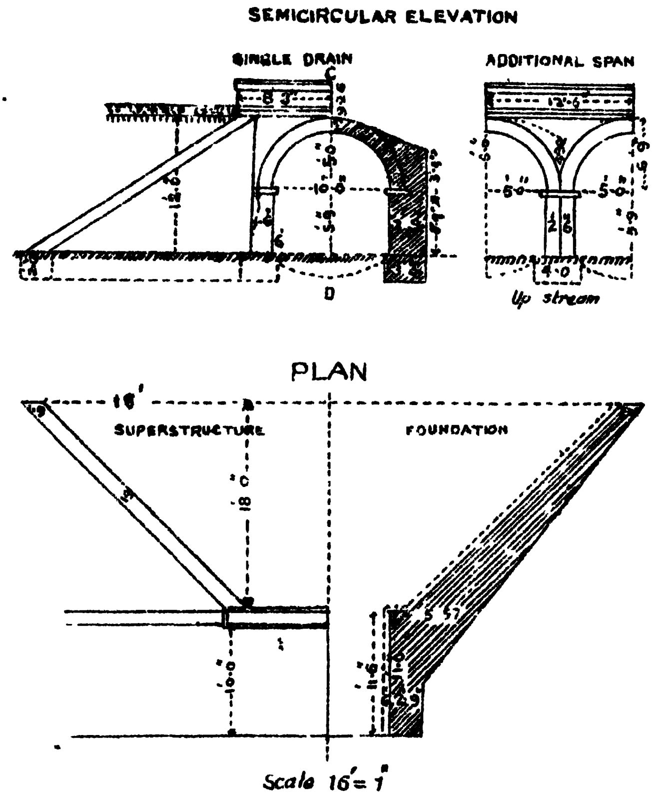
Scale 10'=1"



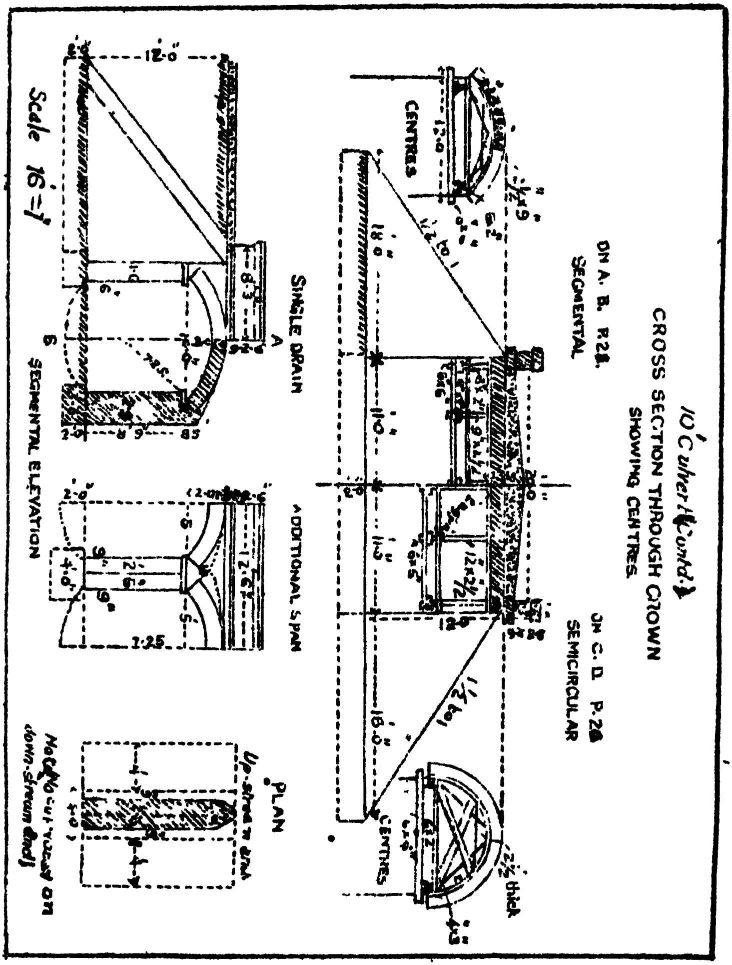
8 FEET CULVERT
SEMICIRCULAR ELEVATION
SINGLE SPAN
ADDITIONAL SPAN
A
B
SUPERSTRUCTURE
FOUNDATION
PLAN
Scale 10' = 1"


8' Culvert (contd.)
Scale 10'=1"
HALF CROSS SECTION THRO. A.B.
PLAN
Of Additional span.
SEGMENTAL ELEVATIONS
SINGLE DRAIN
ADDITIONAL SPAN

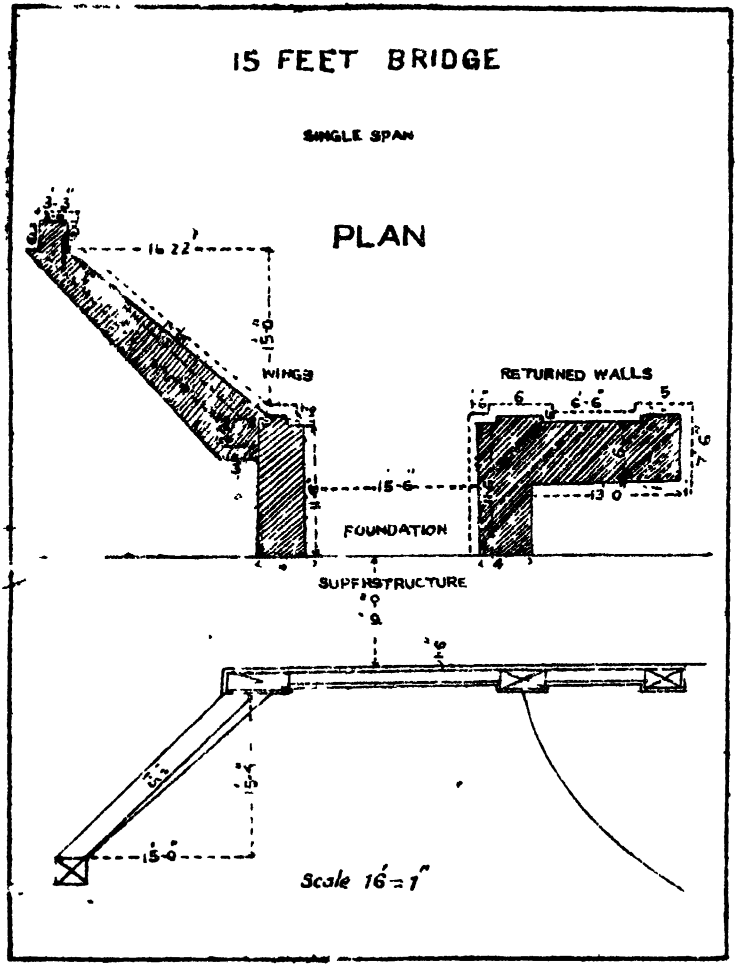
10 FEET CULVERT



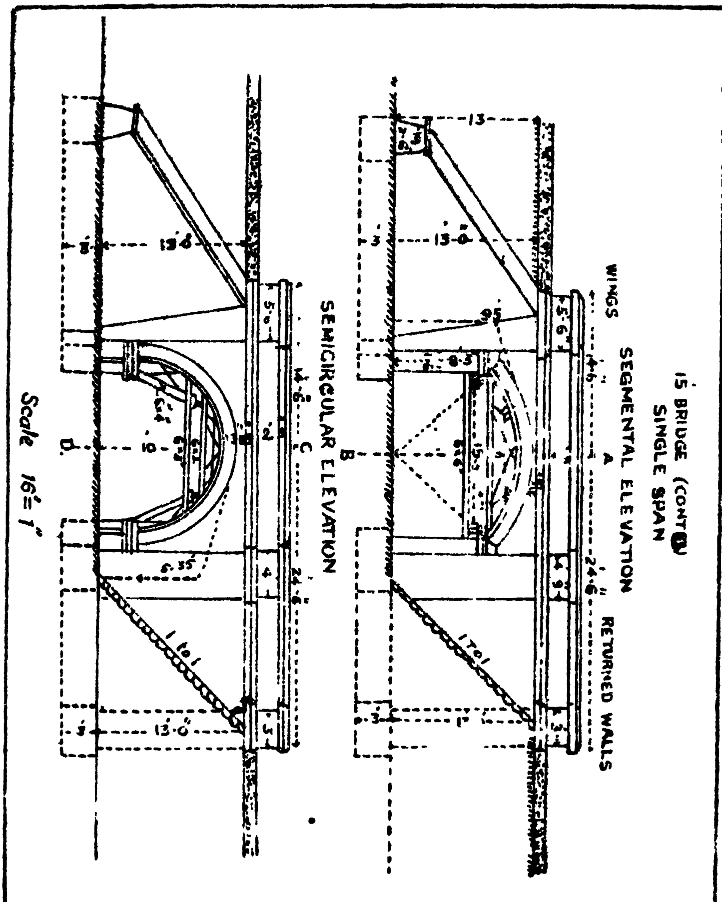
Scale 16' = 1"

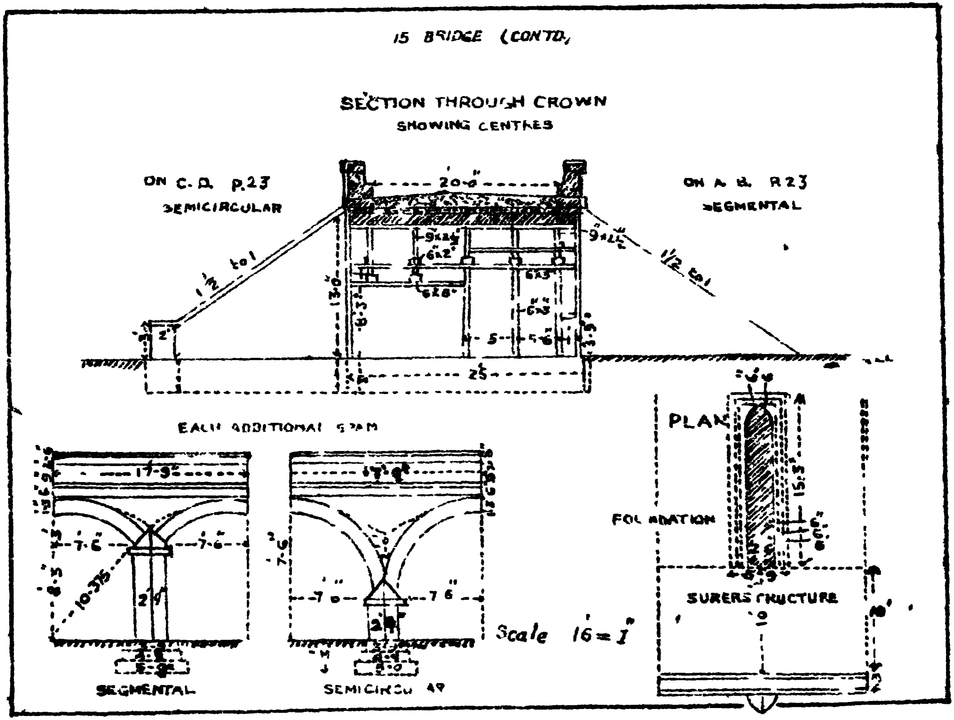


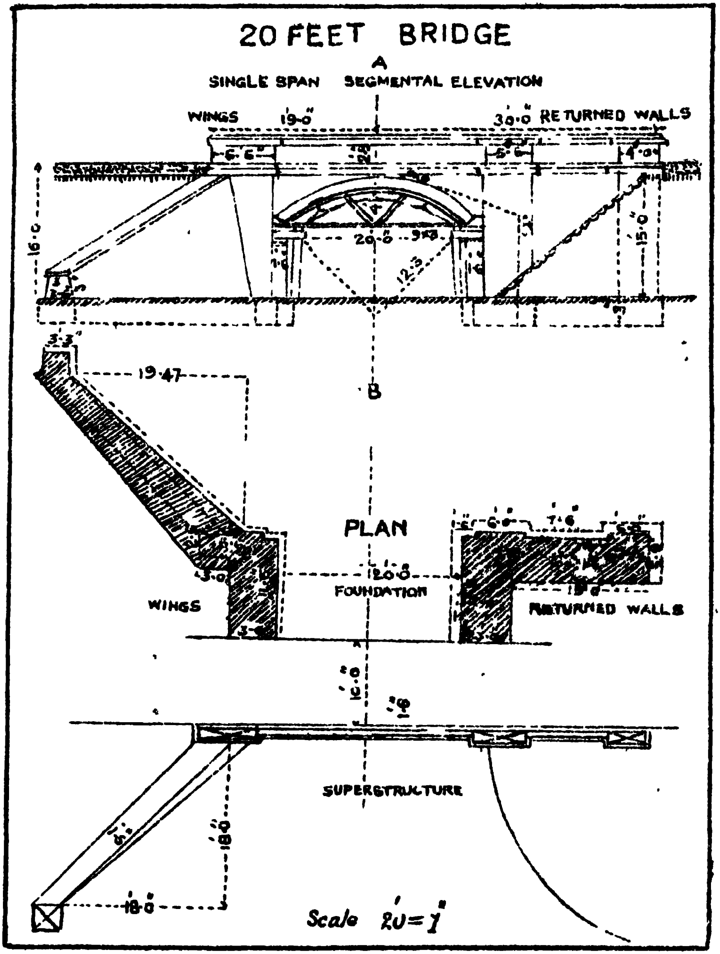
CROSS SECTION THROUGH CROWN
SHOWING CENTRES.
SEGMENTAL
SEMICIRCULAR
CENTRES
CENTRES
SINGLE DRAIN
SEGMENTAL ELEVATION
ADDITIONAL SPAN
PLAN

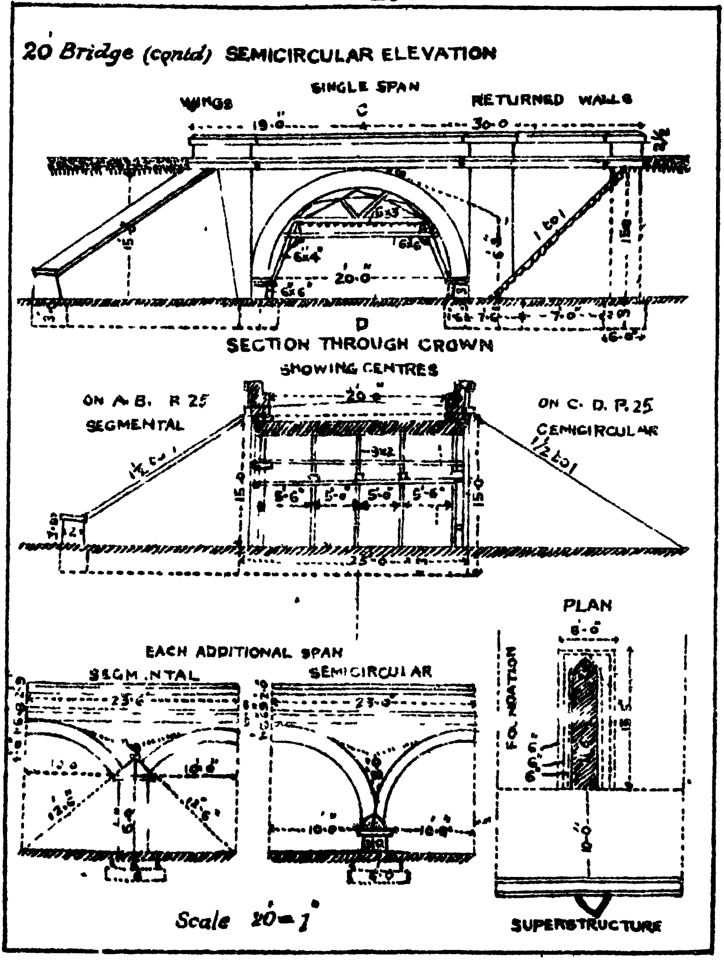


15 FEET BRIDGE
SINGLE SPAN
PLAN
WINGS
RETURNED WALLS
FOUNDATION
SUPERSTRUCTURE
Scale 16' = 1"

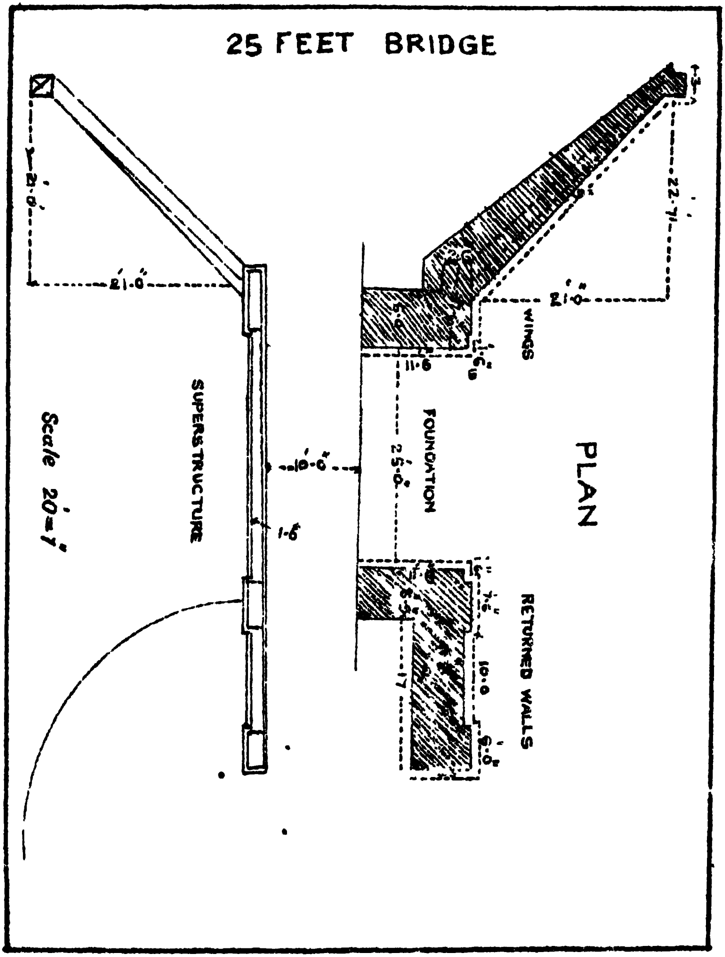

15 BRIDGE (CONTD)
SINGLE SPAN
SEGMENTAL ELEVATION
WINGS
RETURNED WALLS
SEMICIRCULAR ELEVATION
Scale 16' = 1"


15 BRIDGE (CONTD.
SECTION THROUGH CROWN
SHOWING CENTRES
ON C.D. P.23
SEMICIRCULAR
ON A.B. P.23
SEGMENTAL
1½ to 1
1/2 to 1
20-0
13-0
25
EACH ADDITIONAL SPAN
SEGMENTAL
PLAN
FOUNDATION
SUPERSTRUCTURE
Scale 16' = 1"


20 FEET BRIDGE
A
SINGLE SPAN SEGMENTAL ELEVATION
WINGS
RETURNED WALLS
B
PLAN
FOUNDATION
WINGS
RETURNED WALLS
SUPERSTRUCTURE
Scale 20′=1″

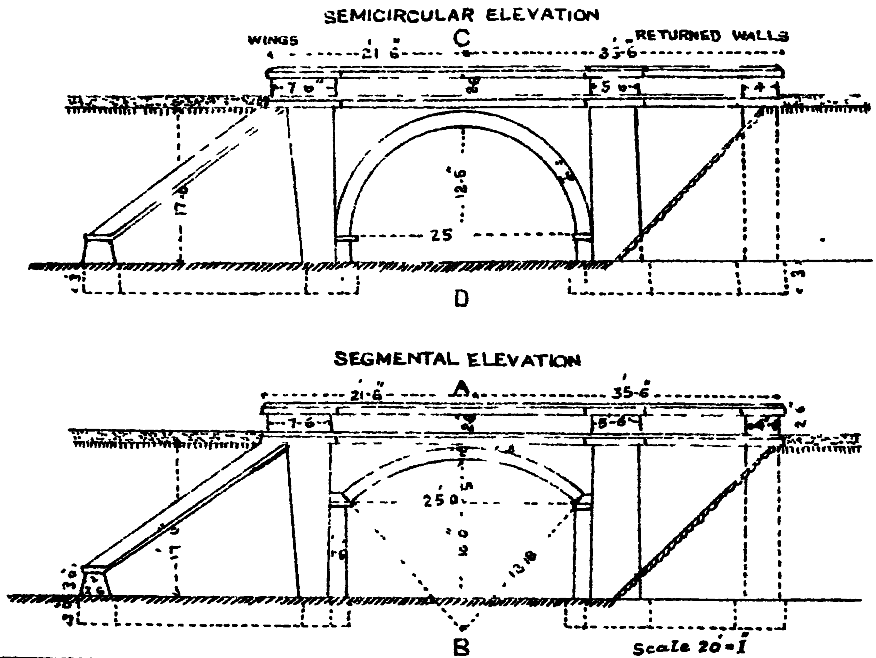

20' Bridge (contd) SEMICIRCULAR ELEVATION
SINGLE SPAN
WINGS
C
RETURNED WALLS
19'·0"
30·0
20·0
6x3
6x4"
6x6"
1 to 1
D
SECTION THROUGH CROWN
SHOWING CENTRES
ON A. B. P. 25
SEGMENTAL
ON C. D. P. 25
SEMICIRCULAR
1½ to 1
20'·0"
3x2
5'·6"
15·0
23'·6
EACH ADDITIONAL SPAN
SEGMENTAL
SEMICIRCULAR
23'·6
10'·0"
PLAN
8·0
FOUNDATION
SUPERSTRUCTURE
Scale 20'=1"

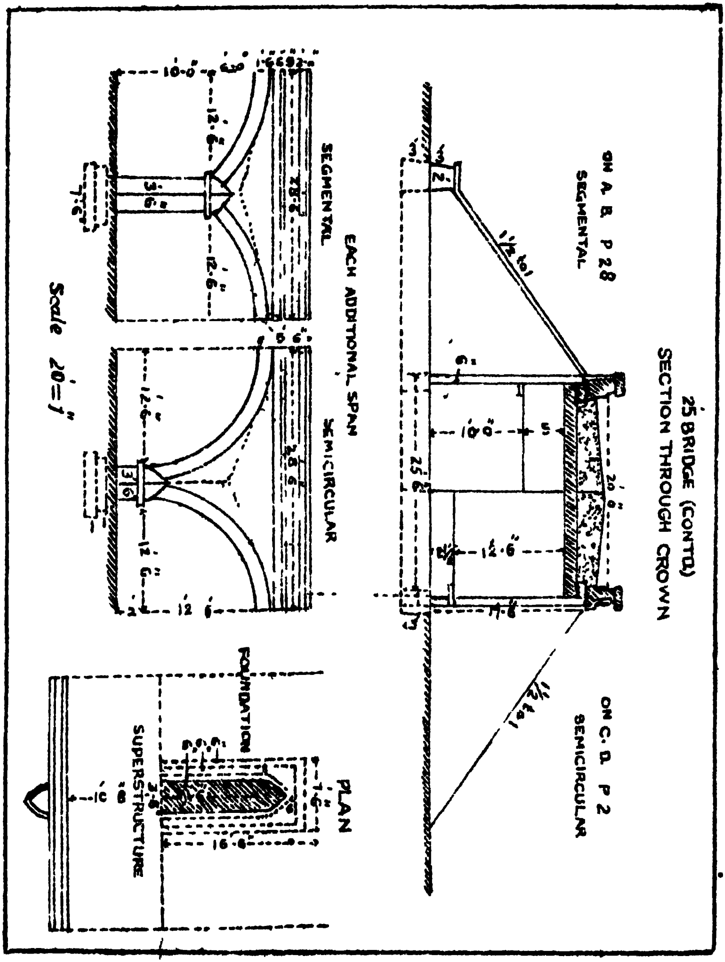
25 FEET BRIDGE

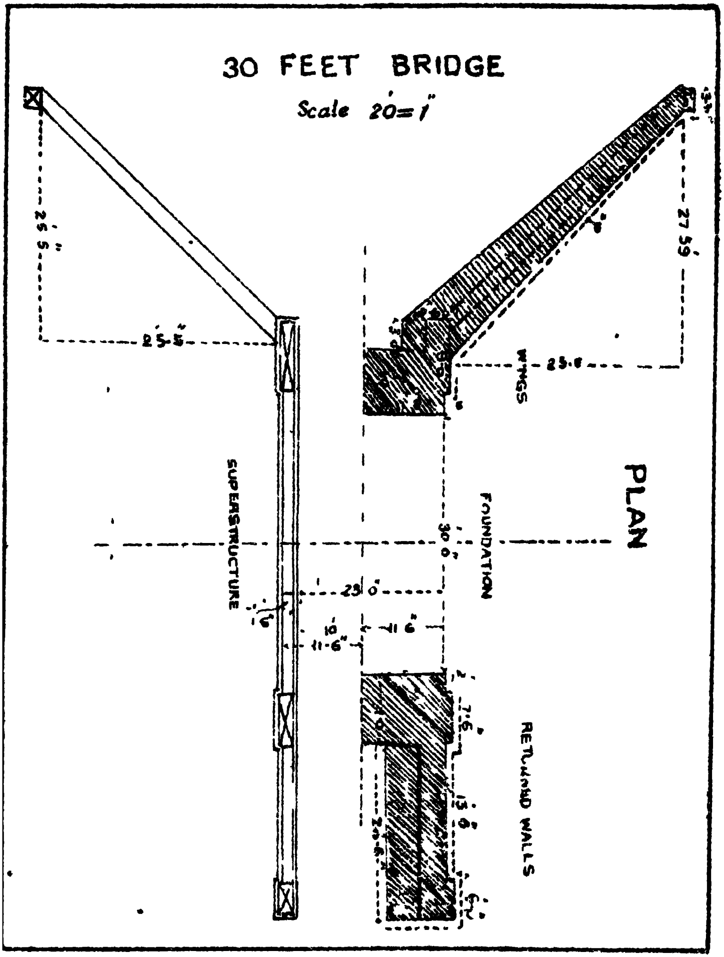


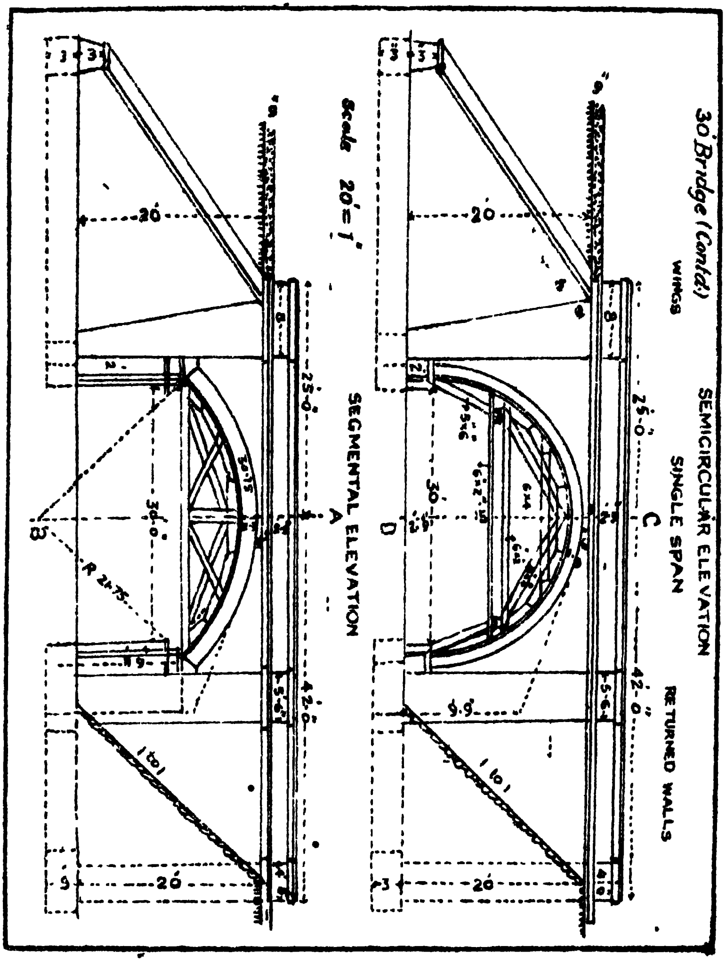
25' Bridge (Continued)

SINGLE SPAN

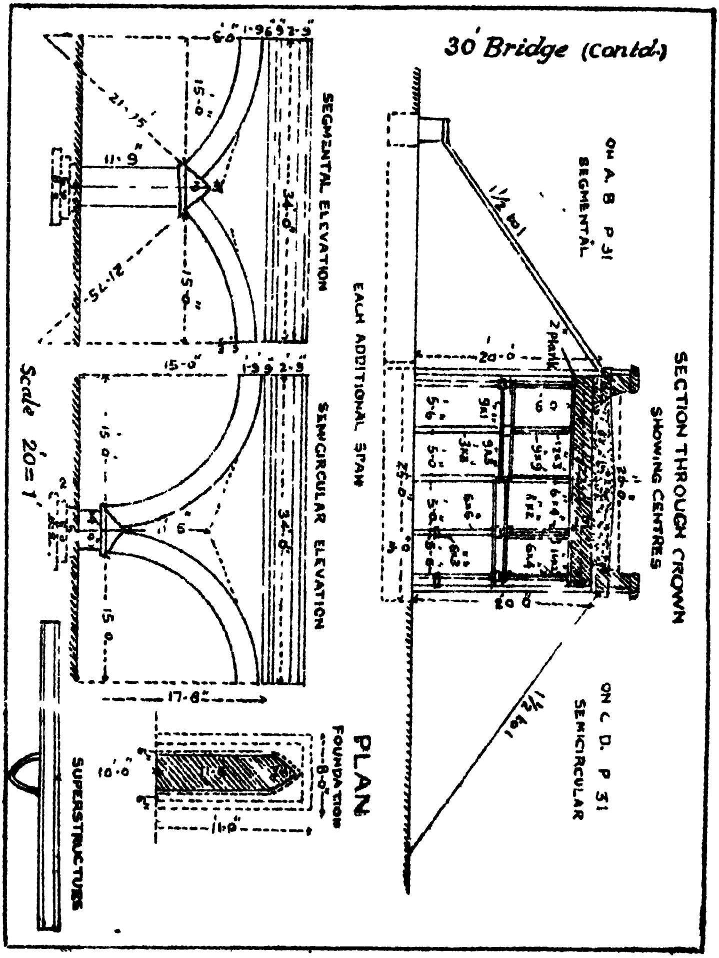



25' BRIDGE (CONTD.)
SECTION THROUGH CROWN
ON A. B. P 28
SEGMENTAL
ON C. D. P 2
SEMICIRCULAR
EACH ADDITIONAL SPAN
SEGMENTAL
SEMICIRCULAR
PLAN
FOUNDATION
SUPERSTRUCTURE
Scale 20'=1"


30 FEET BRIDGE
Scale 20'=1"
PLAN
SUPERSTRUCTURE
FOUNDATION
WINGS
RETURNED WALLS
25' 5"
25' 5"
27' 5"
25' 6"
30' 0"
23' 0"
10'
11' 6"
11' 6"
7' 6"
13' 6"


30' Bridge (Contd.)
WINGS
SEMICIRCULAR ELEVATION
SINGLE SPAN
RETURNED WALLS
SEGMENTAL ELEVATION
Scale 20' = 1"

30' Bridge (Contd.)



TEMPORARY TIMBER BRIDGES.

FIG. 1 DESIGN FOR A TIMBER BRIDGE WIDTH OF EACH BAY 10'

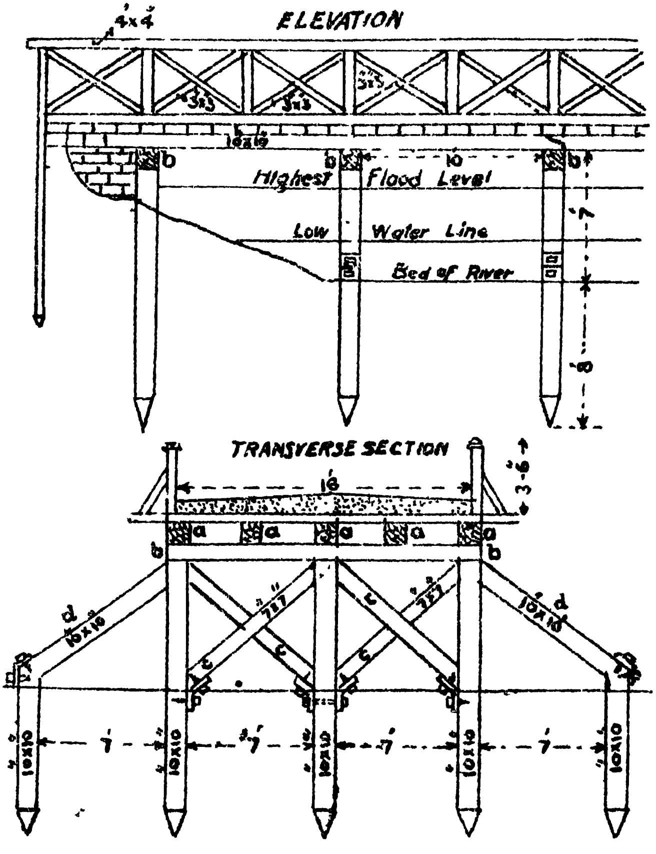
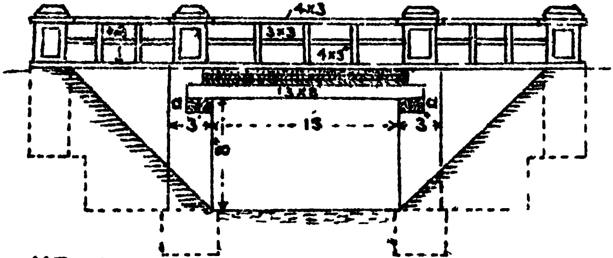


FIG. 2

DESIGN FOR A TIMBER BRIDGE SPAN 15 FT.

ELEVATION

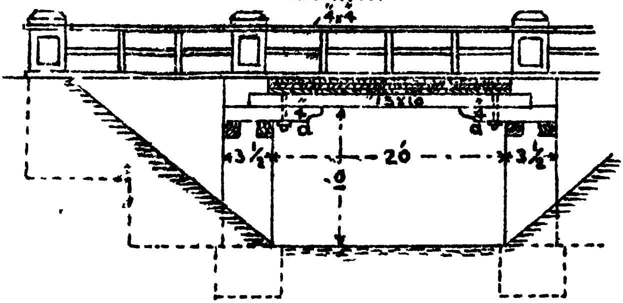


N.B. Central interval between Girders 1·5 Ft.

FIG. 3

DESIGN FOR A TIMBER BRIDGE SPAN 20 FT.

ELEVATION



N.B. Central interval between Girders 1·636 Ft.

FIG. 4

DESIGN FOR A TIMBER BRIDGE WIDTH OF EACH BAY 20'

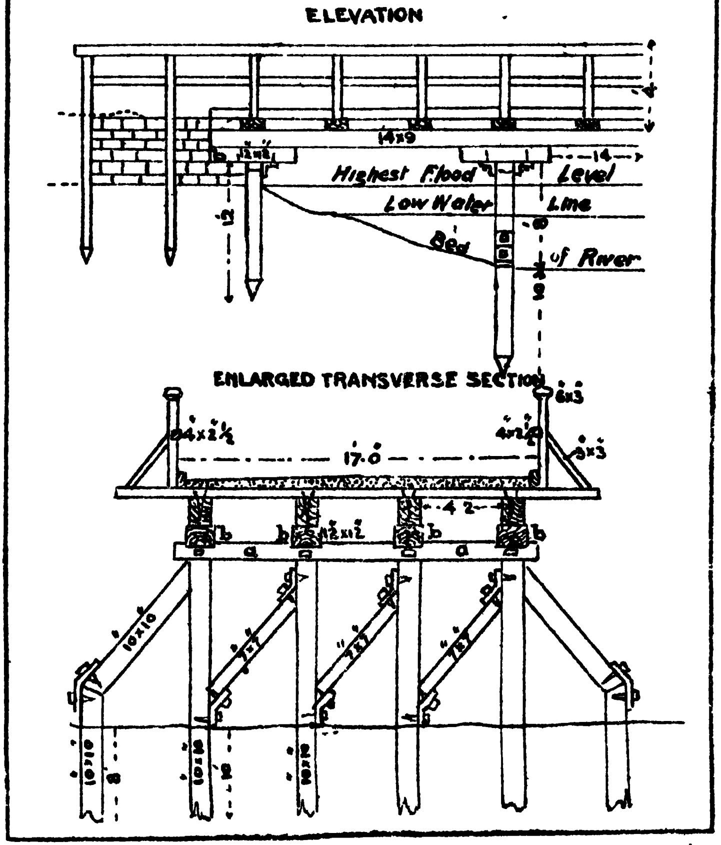


FIG. 5
DESIGN FOR A TIMBER BRIDGE WIDTH OF EACH BAY 25'

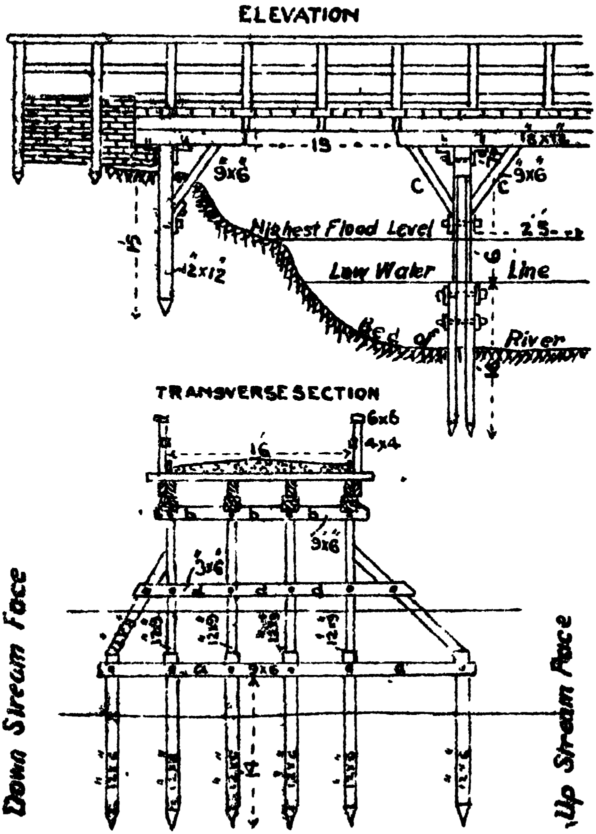


FIG 6

DESIGN FOR A TIMBER BRIDGE SPAN 20 FT.

ELEVATION

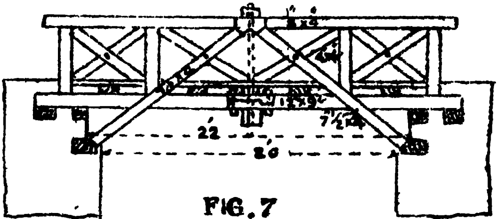


FIG. 7

DESIGN FOR A TIMBER BRIDGE SPAN 30 FT.

ELEVATION

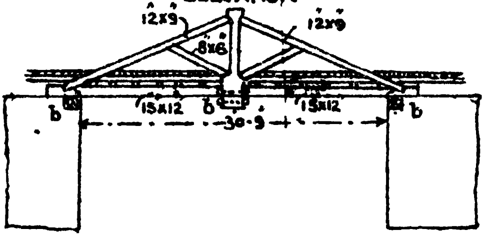
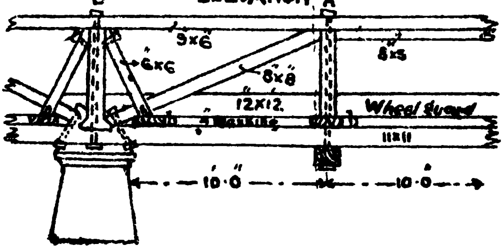


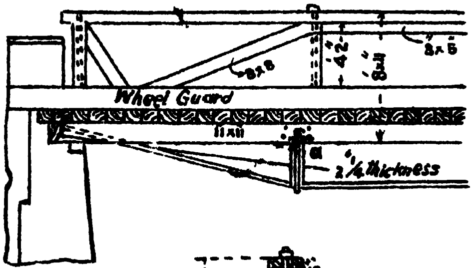
FIG. 8

DESIGN FOR A TIMBER BRIDGE SPAN 30 FT

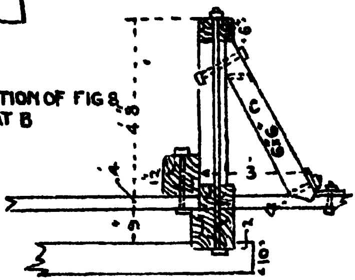
ELEVATION



PART LONGITUDINAL SECTION OF FIG. 8



CROSS SECTION OF FIG 8
AT B



CROSS SECTION OF FIG. 8
AT A

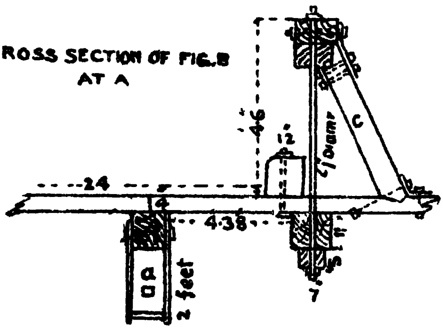
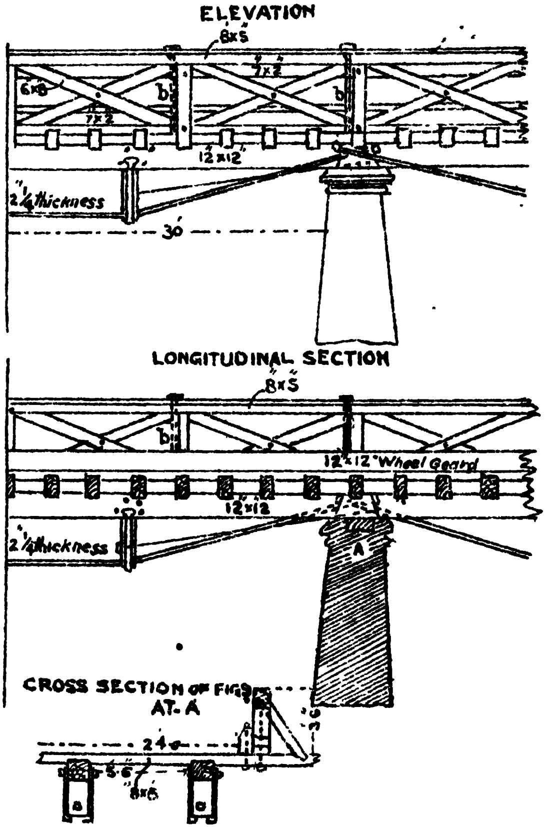


FIG. 9

DESIGN FOR A TIMBER BRIDGE SPAN 30 FT.



ENLARGED CROSS SECTION OF FIG. 9 AT. B.

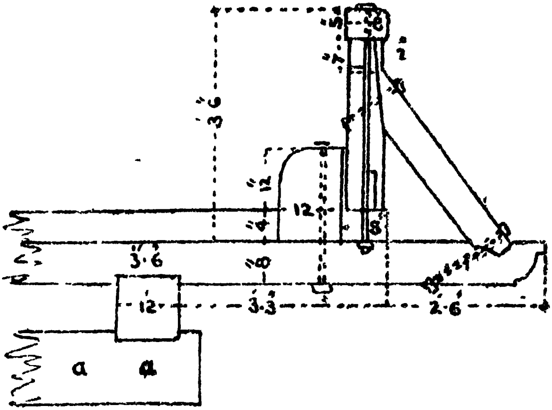
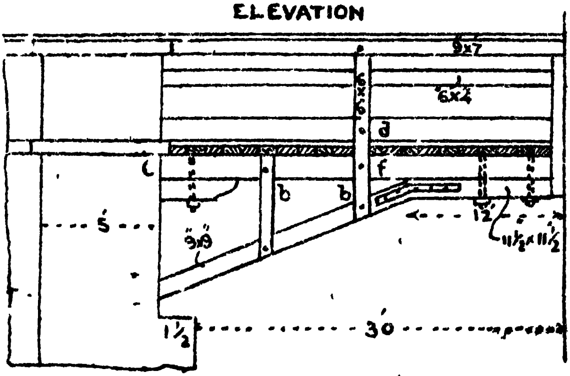
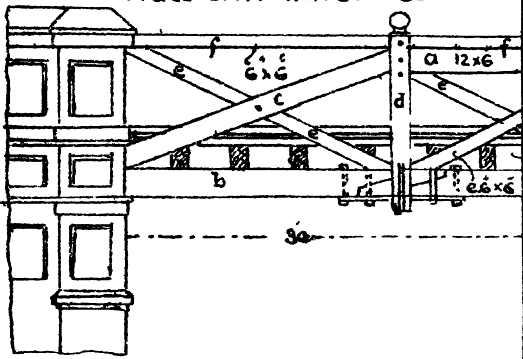


FIG. 10
DESIGN FOR A TIMBER BRIDGE SPAN 30 FT.
ELEVATION



Inclination of Struts 25 to the Horizon.

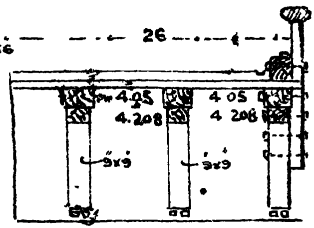
FIG. 11 SPAN FROM 30 TO 35



DETAILS OF FIG 10

FIG. 10. A

PART CROSS SECTION THRO CENTRE OF SPAN



- CROSS SECTION THROUGH QUEEN -
- POST -

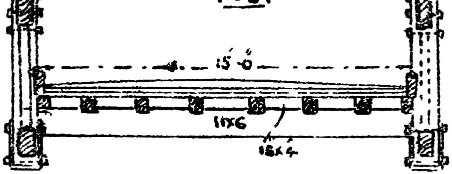


FIG. 10 B

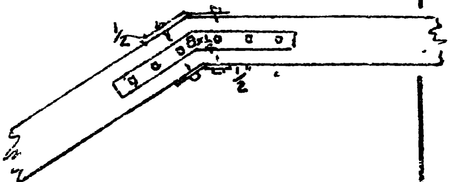


FIG. 12

DESIGN FOR A TIMBER BRIDGE WIDTH OF EACH BAY 35'

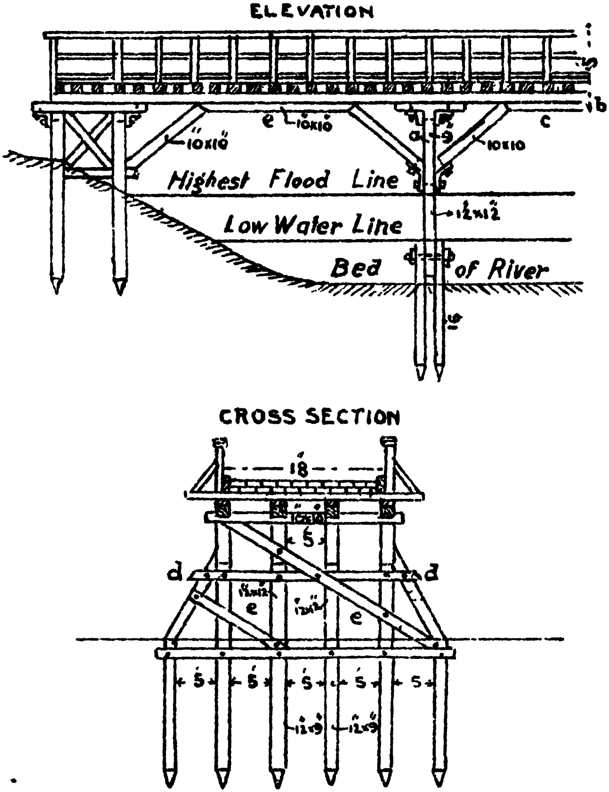
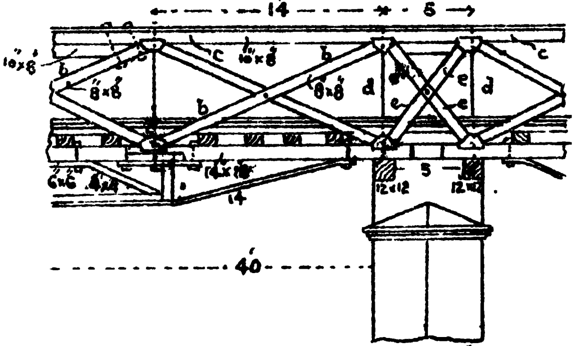


FIG. 13

DESIGN FOR A TIMBER BRIDGE SPAN FROM 30' TO 40'

ELEVATION



CROSS SECTION THROUGH QUEEN POST

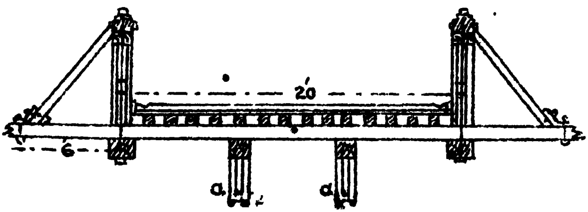
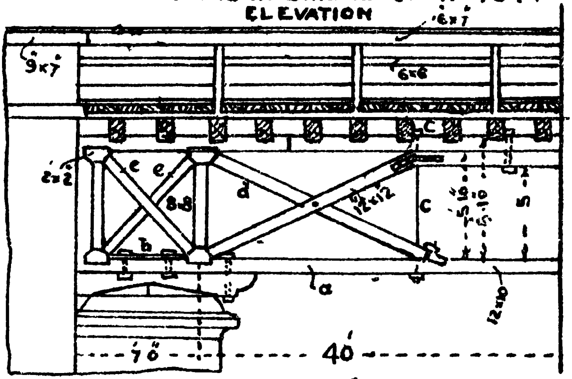


FIG. 14

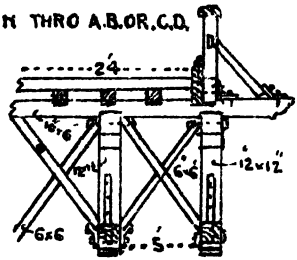
DESIGN FOR A TIMBER BRIDGE SPAN 40 FT

ELEVATION



Inclination of Struts 22° to the Horizon.

PART SECTION THRO A.B.OR.C.D.



Scarf on Tie Beam.

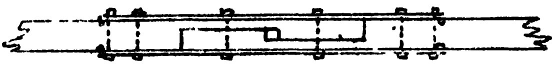
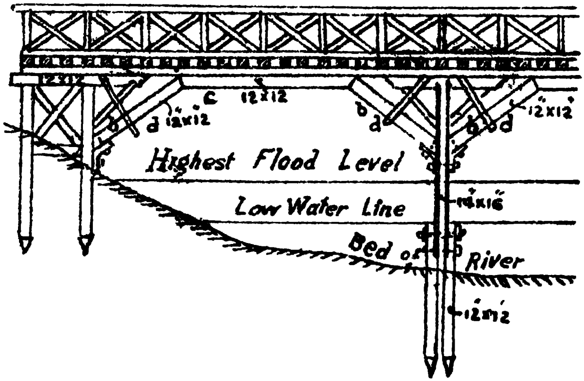


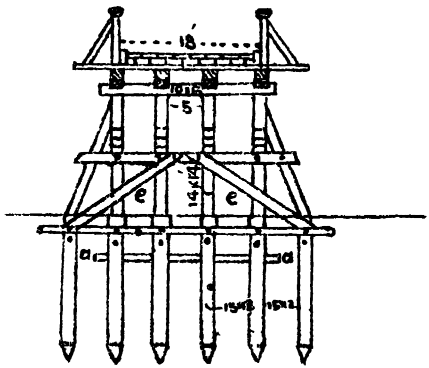
FIG. 15

DESIGN FOR A TIMBER BRIDGE WIDTH OF EACH BAY 45'

ELEVATION



CROSE SECTION



JOINTS, SCARFS, SHOES, &c.

FIG. 16

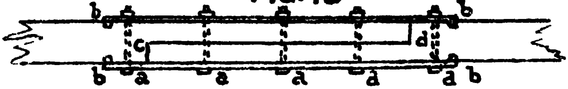


FIG. 17

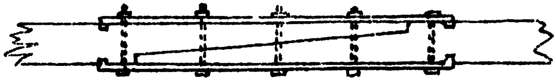


FIG. 18

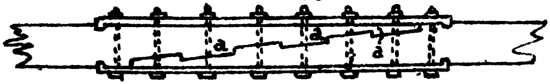


FIG. 19

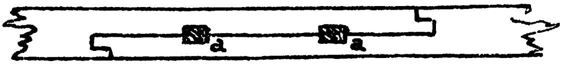


FIG. 20

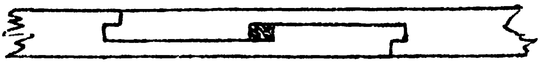


FIG. 21

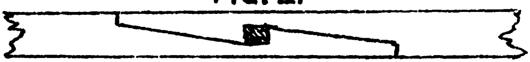


FIG. 22

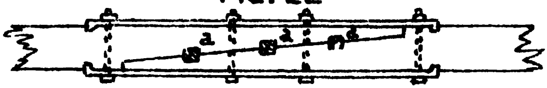


FIG. 23

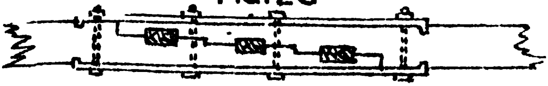


FIG. 24

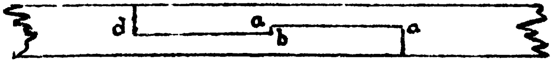


FIG. 25

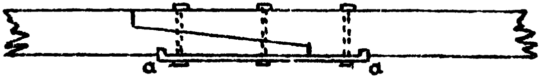


FIG. 26

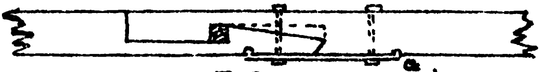


FIG. 27

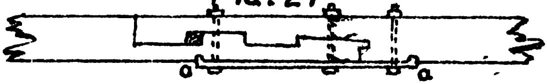


FIG. 28

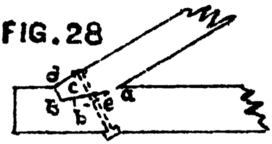


FIG. 29

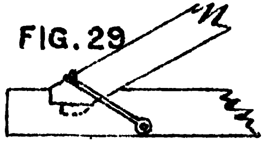
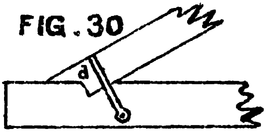


FIG. 30



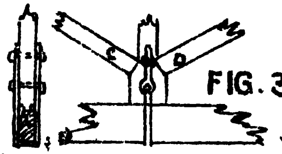


FIG. 31

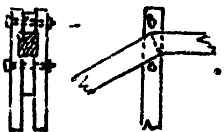


FIG. 32

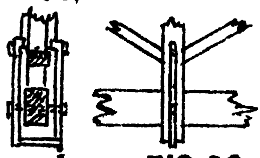
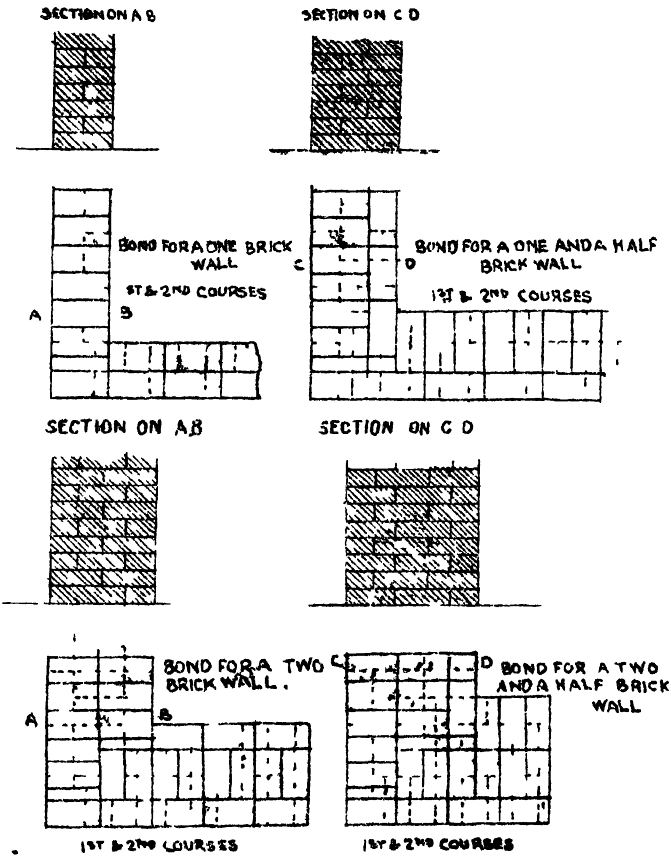
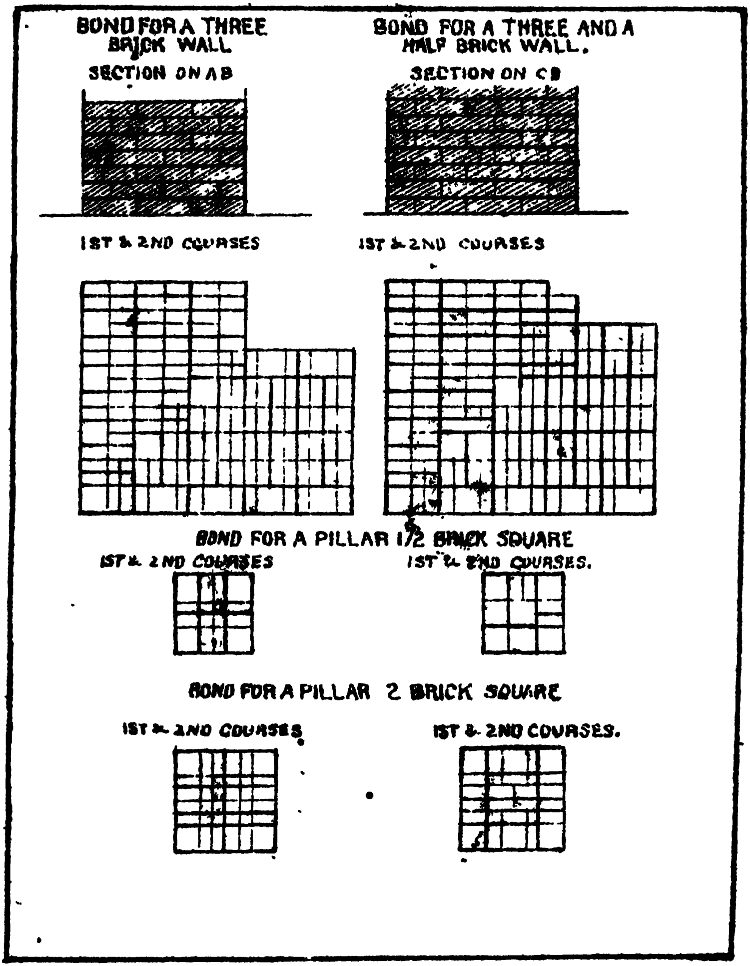


FIG. 33

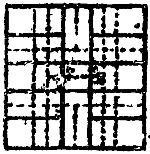
BUILDING CONSTRUCTION - DETAILS



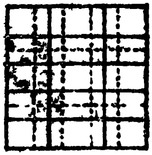

BOND FOR A THREE BRICK WALL
SECTION ON AB
1ST & 2ND COURSES
BOND FOR A THREE AND A HALF BRICK WALL.
SECTION ON CD
1ST & 2ND COURSES
BOND FOR A PILLAR 1½ BRICK SQUARE
1ST & 2ND COURSES
1ST & 2ND COURSES.
BOND FOR A PILLAR 2 BRICK SQUARE
1ST & 2ND COURSES
1ST & 2ND COURSES.

BOND FOR A PILLAR 2½ BRICK SQUARE

1ST & 2ND COURSES

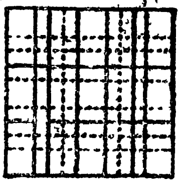


1ST & 2ND COURSES.



BOND FOR A PILLAR 3 BRICK SQUARE

1ST & 2ND COURSES.

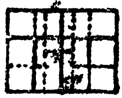


BOND FOR A PILLAR 2×1½ BRICKS

1ST & 2ND COURSES



1ST & 2ND COURSES.

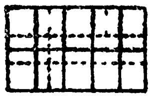


BOND FOR A PILLAR 2½×1½ BRICKS

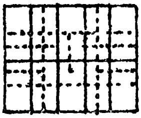
1ST & 2ND COURSES



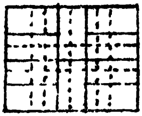
1ST & 2ND COURSES.



BOND FOR A PILLAR 2½ × 2 BRICKS.



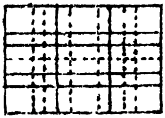
1ST & 2ND COURSES



1ST & 2ND COURSES

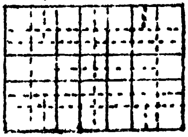
BOND FOR PILLAR 3 × 2 BRICKS

1ST & 2ND COURSES.



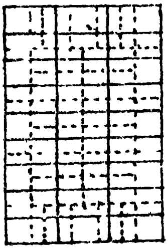
BOND FOR PILLAR 3¼ × 2½ BRICKS

1ST. & 2ND COURSES.



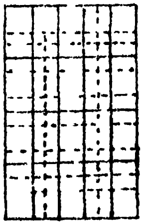
BOND FOR A PILLAR 4 × 3 BRICKS

1ST & 2ND. COURSES



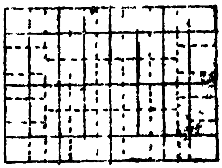
BOND FOR A PILLAR 4 × 2½ BRICKS,

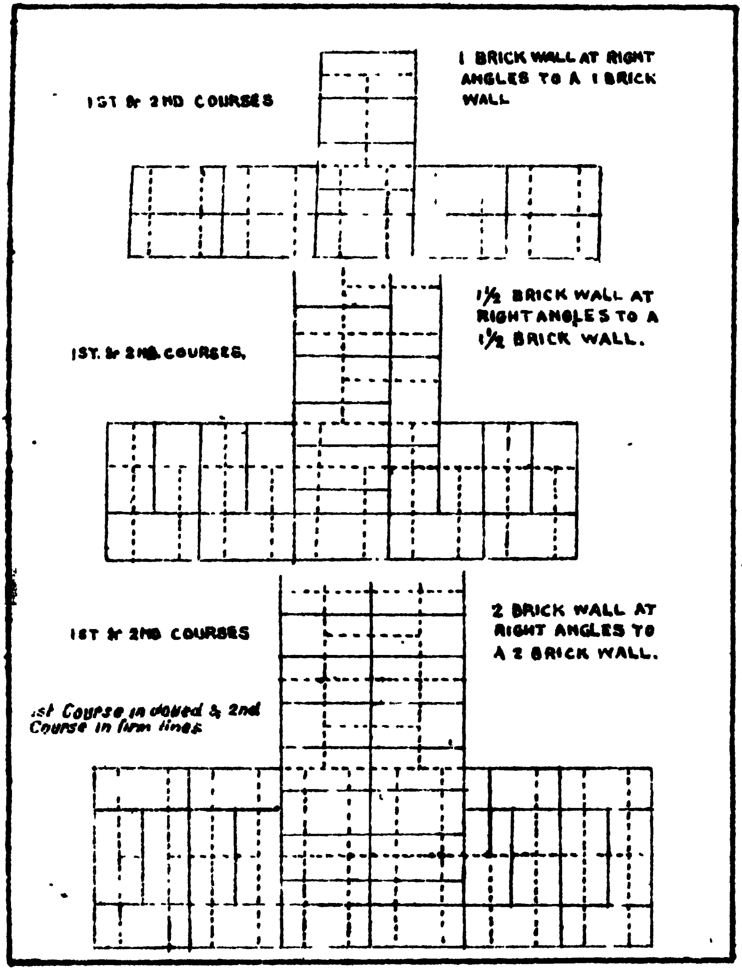
1ST & 2ND COURSES



BOND FOR A PILLAR 4½ × 3 BRICKS.

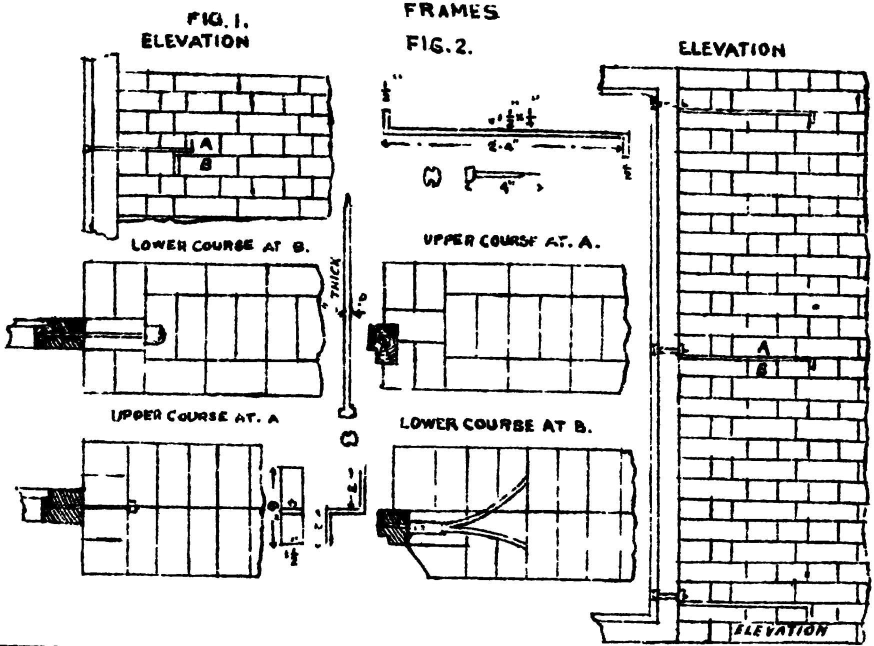
1ST & 2ND COURSES. ←

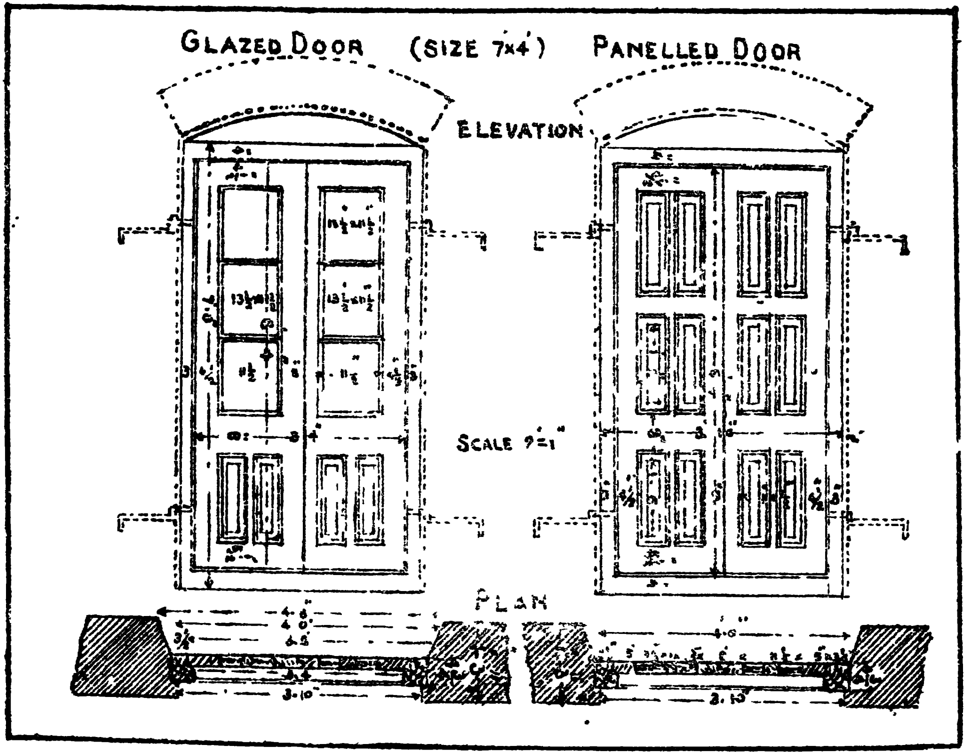




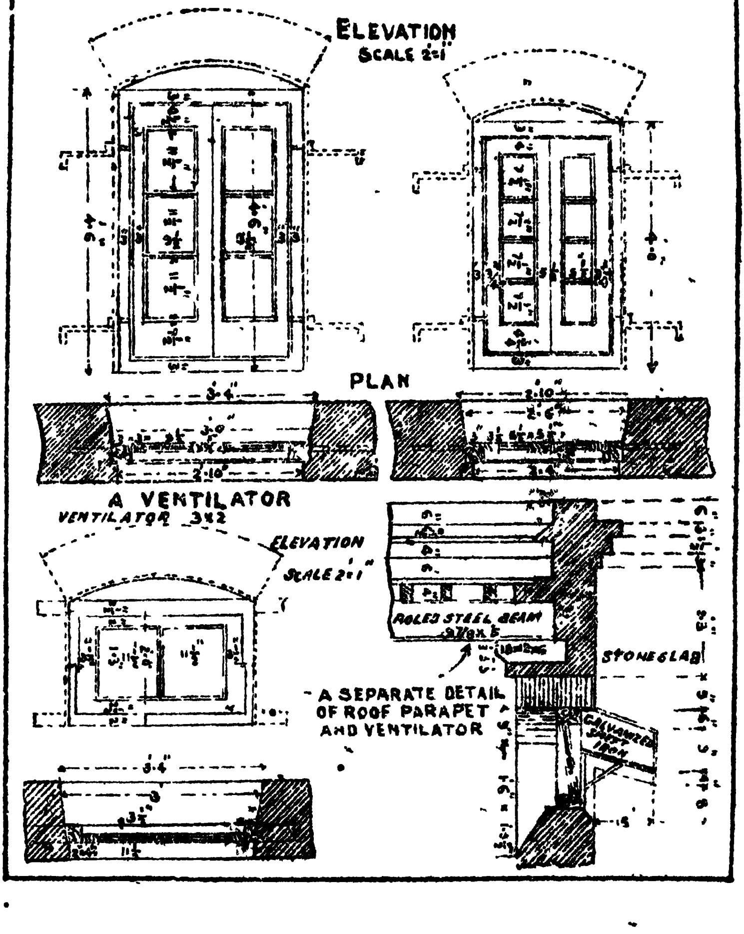
1ST & 2ND COURSES
1 BRICK WALL AT RIGHT ANGLES TO A 1 BRICK WALL
1ST. & 2ND COURSES.
1½ BRICK WALL AT RIGHT ANGLES TO A 1½ BRICK WALL.
1ST & 2ND COURSES
2 BRICK WALL AT RIGHT ANGLES TO A 2 BRICK WALL.
1st Course in dotted & 2nd Course in firm lines

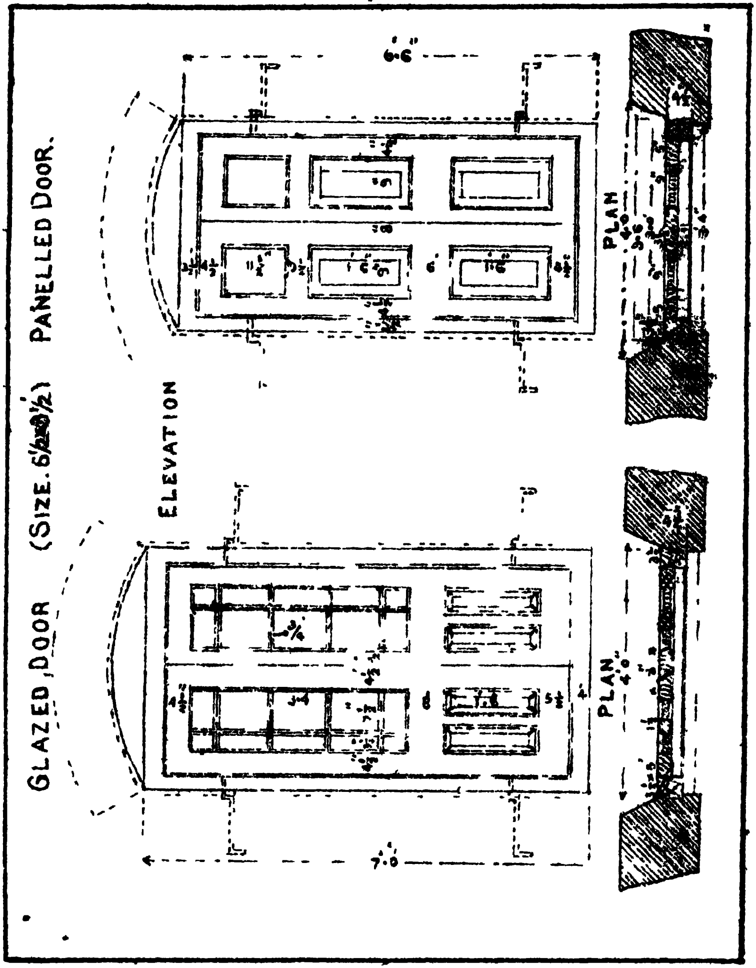
TWO METHODS OF FIXING DOOR FRAMES

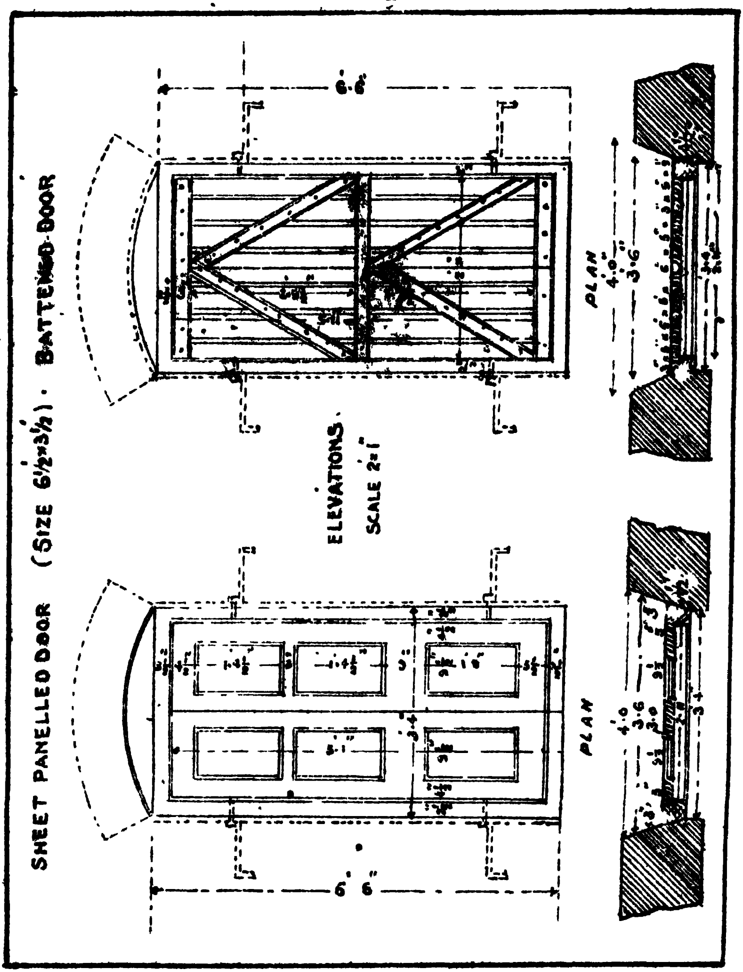


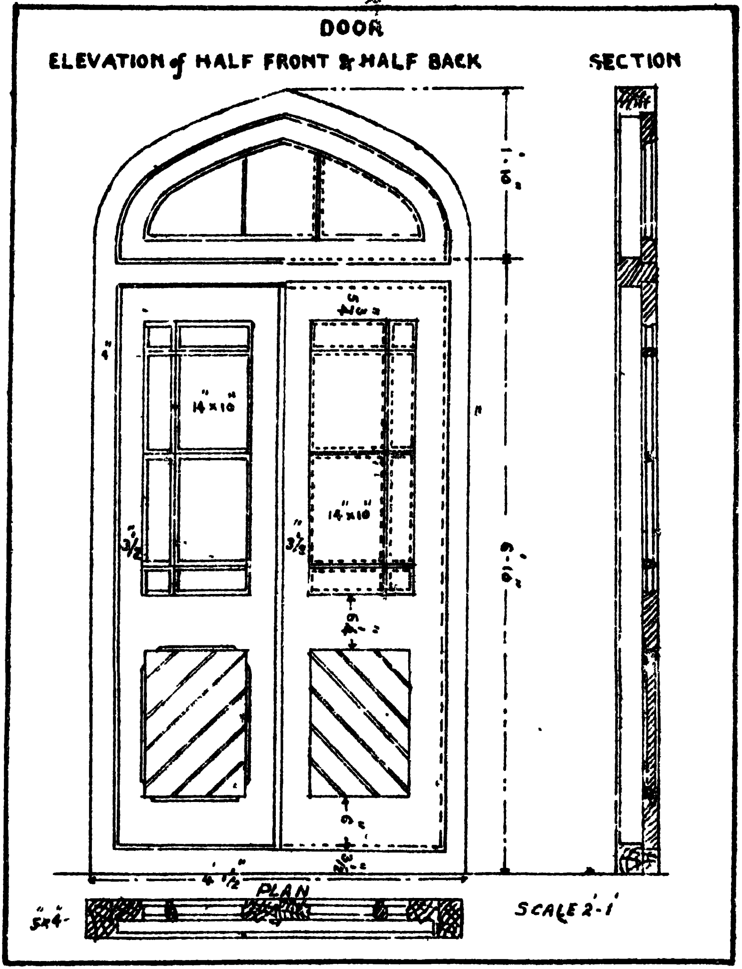

GLAZED DOOR
(SIZE 7x4')
PANELLED DOOR
ELEVATION
SCALE 9"=1'
PLAN
4.6"
4.0"
4.3"
3.10"
4.0
3.10"

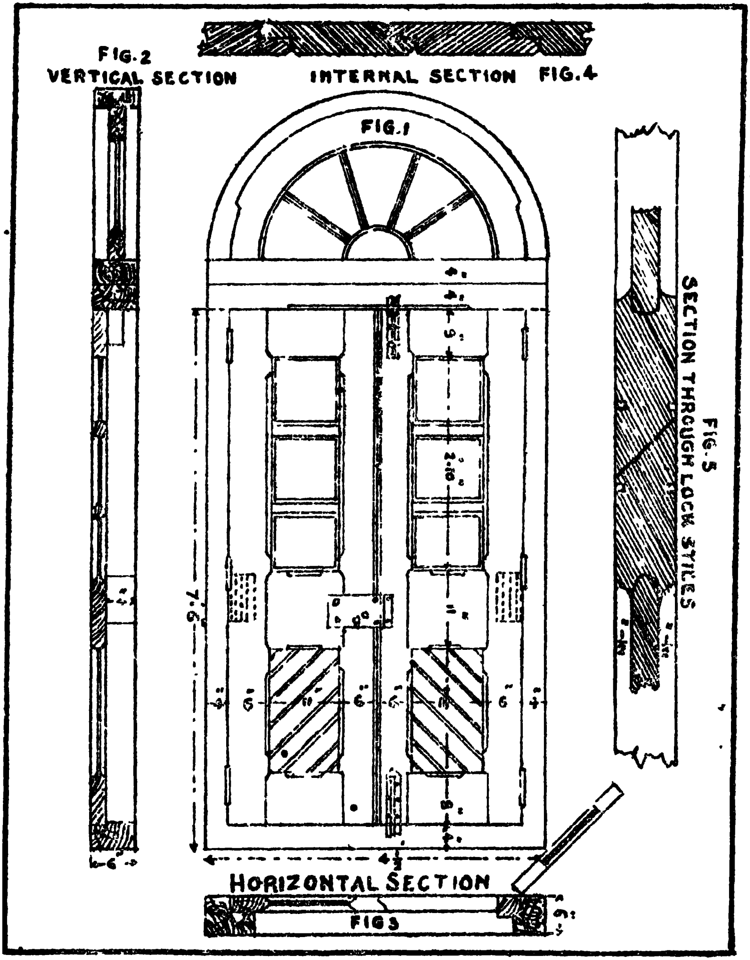
GLAZED WINDOWS

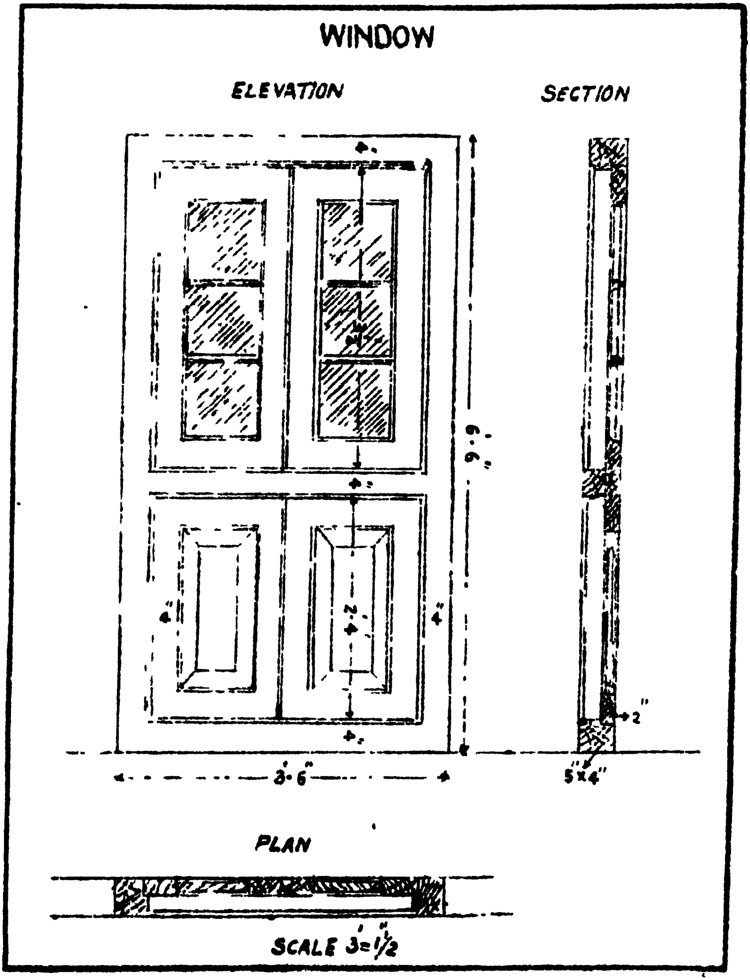


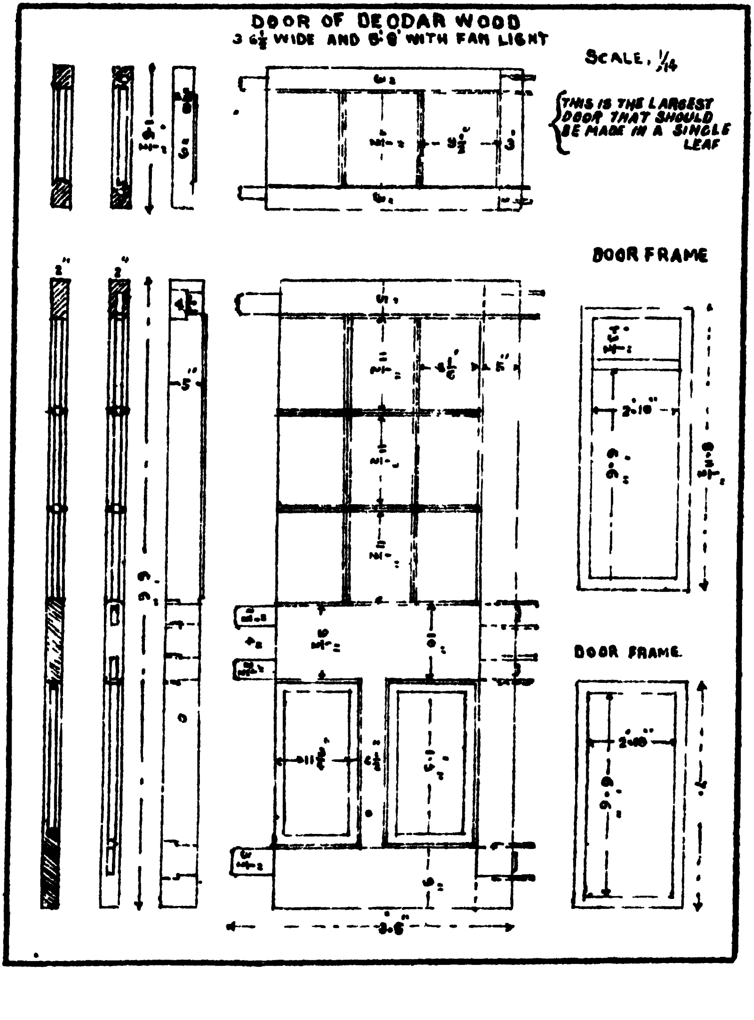

GLAZED DOOR
PANELLED DOOR.
ELEVATION
PLAN
PLAN
7'0"
6'6"

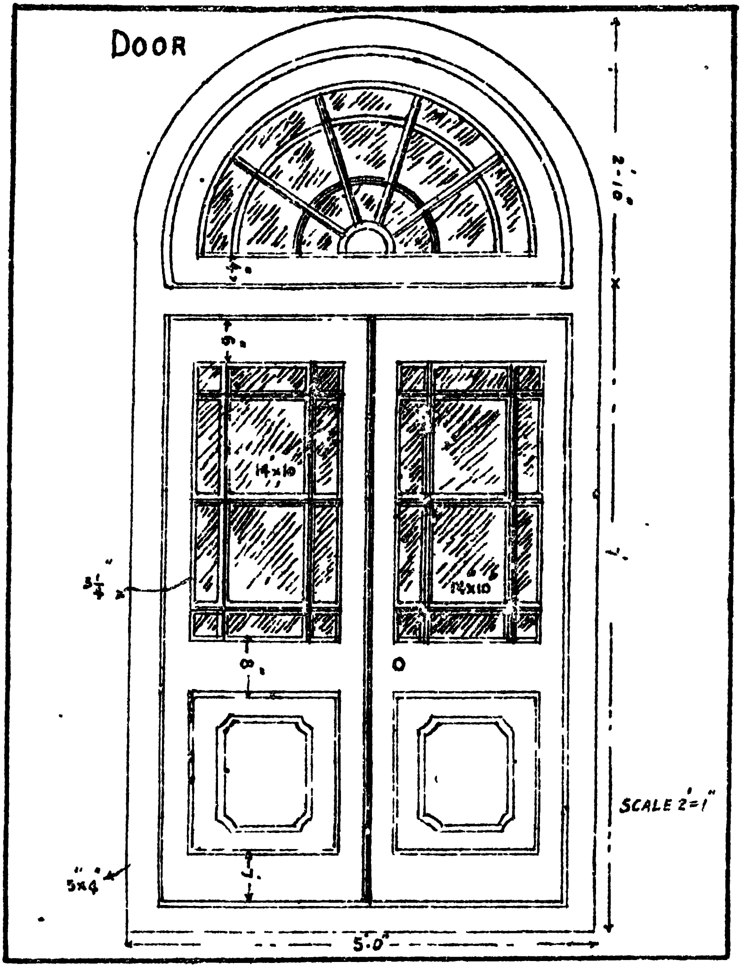

SHEET PANELLED DOOR (SIZE 6½×3½) · BATTENED DOOR
ELEVATIONS
SCALE 2"=1'
PLAN
PLAN
6'6"
6'6"

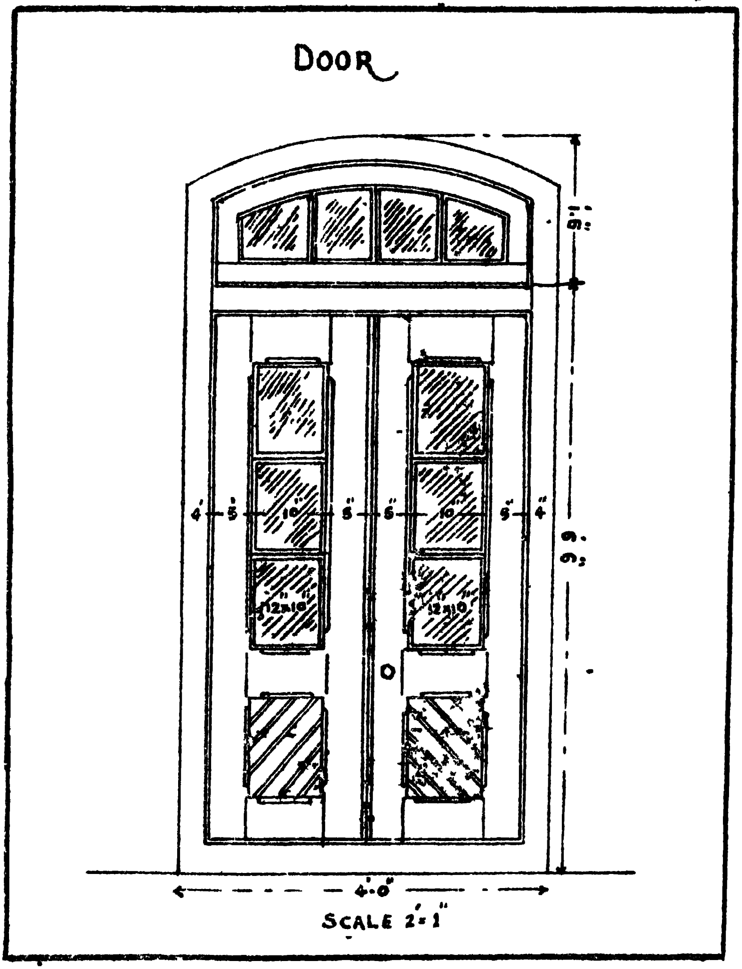

DOOR
ELEVATION of HALF FRONT & HALF BACK
SECTION
14" x 10"
14" x 10"
3½"
3½"
4' 1½"
PLAN
5"x4"
SCALE 2'-1'

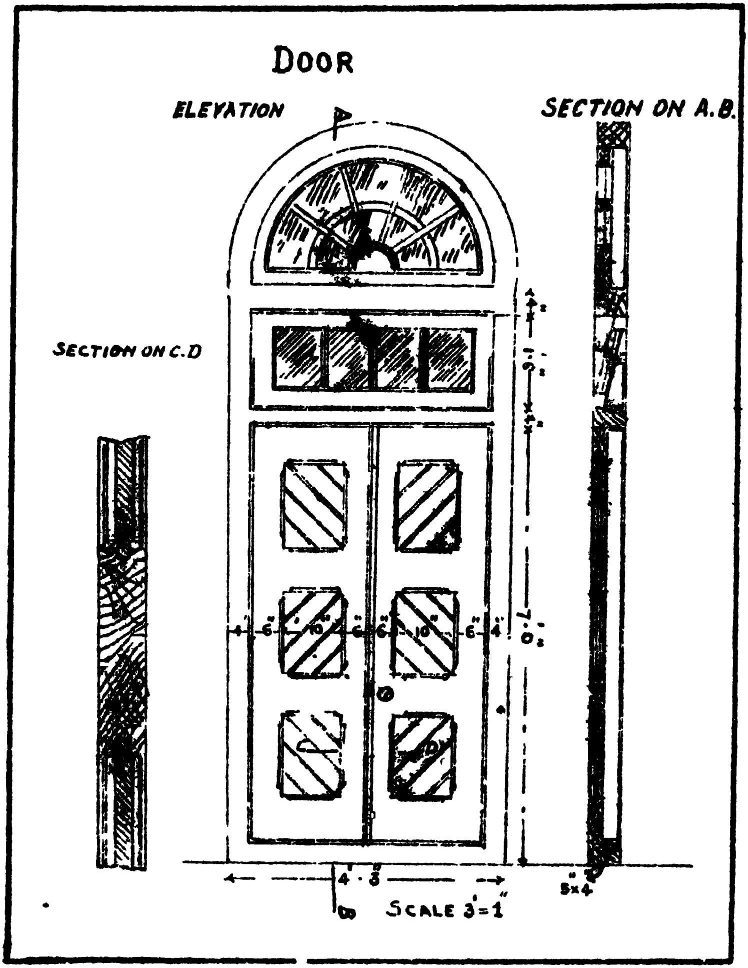

FIG. 2
VERTICAL SECTION
INTERNAL SECTION FIG. 4
FIG. 1
FIG. 5
SECTION THROUGH LOCK STILES
HORIZONTAL SECTION
FIG 3
7.6
4½

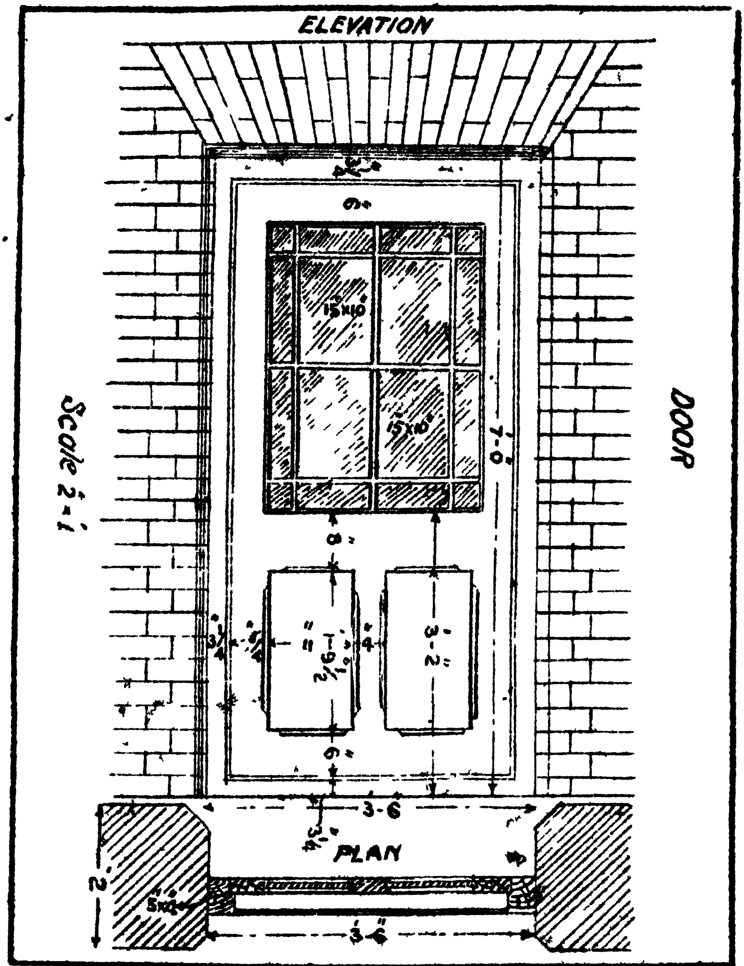

WINDOW
ELEVATION
SECTION
6'-9"
3'-6"
4"
4"
2'-4"
2"
5"x4"
PLAN
SCALE 3'=1/2"

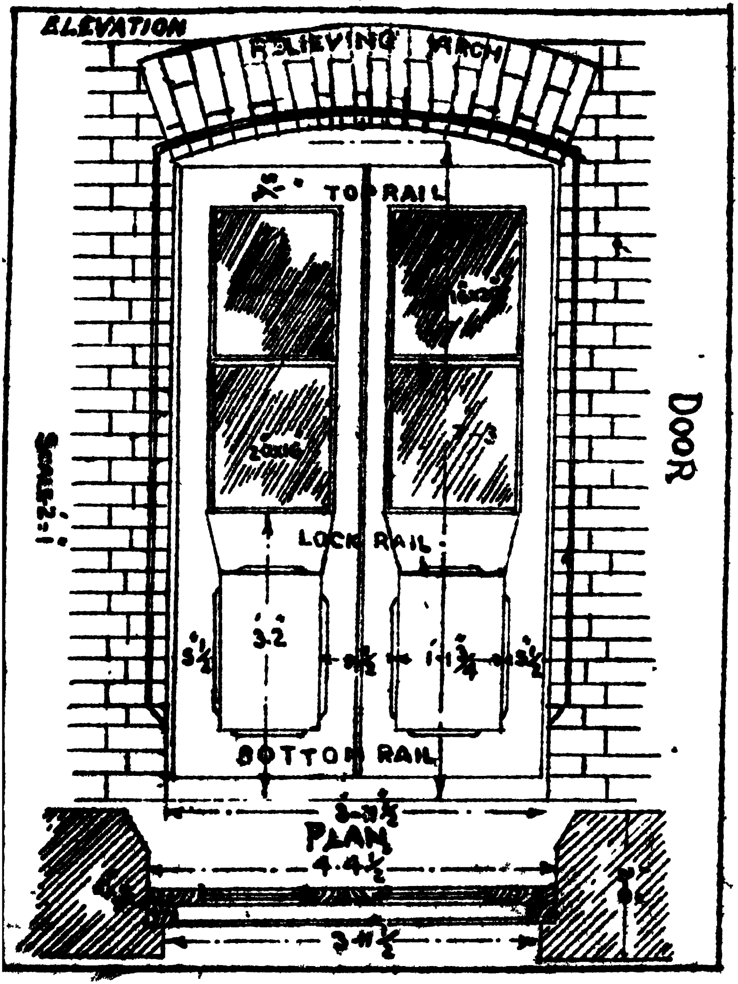

DOOR OF DEODAR WOOD
THIS IS THE LARGEST DOOR THAT SHOULD BE MADE IN A SINGLE LEAF
DOOR FRAME
DOOR FRAME

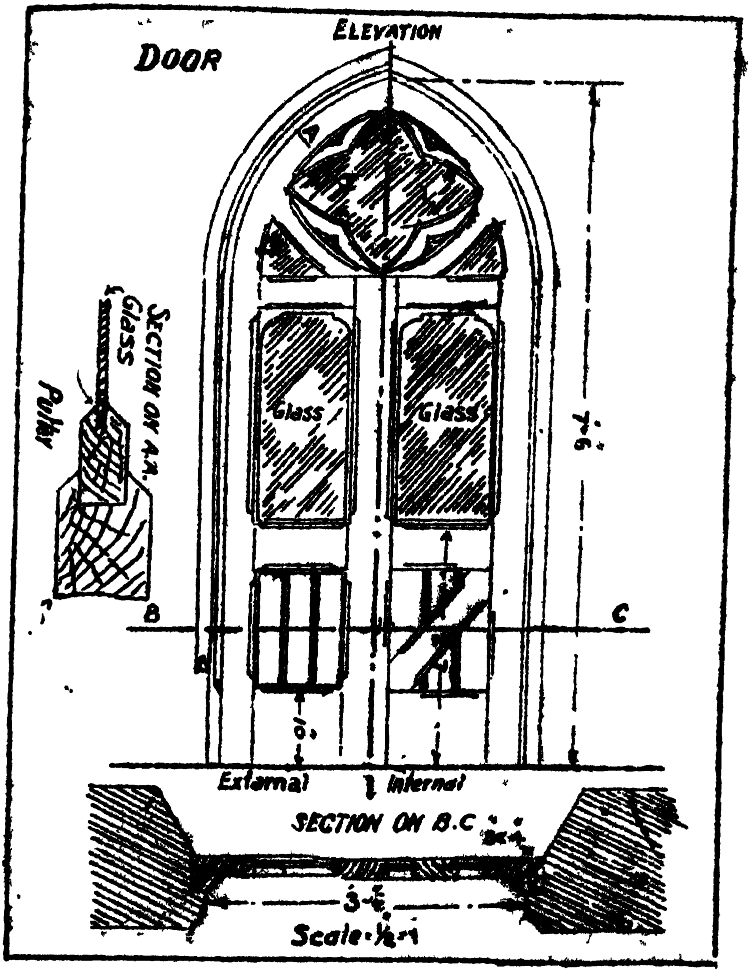

DOOR
2'-10"
14x10
14x10
5x4
SCALE 2'=1"
5'-0"

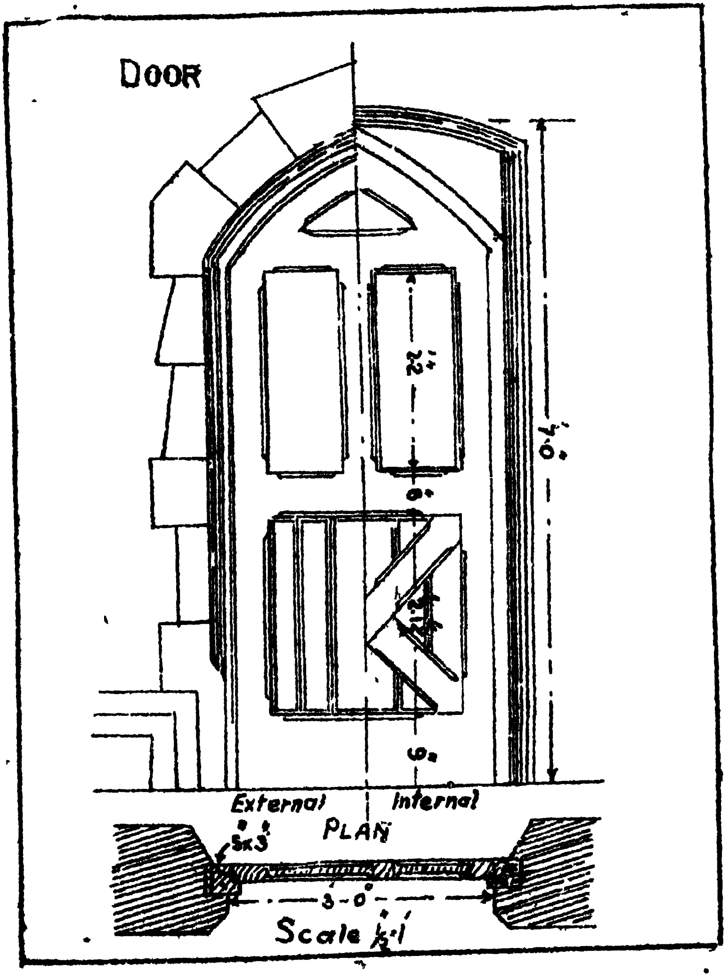

DOOR
4"
5"
10"
5"
5"
10"
5"
4"
12"x10"
12"x10"
4'-0"
SCALE 2'=1"

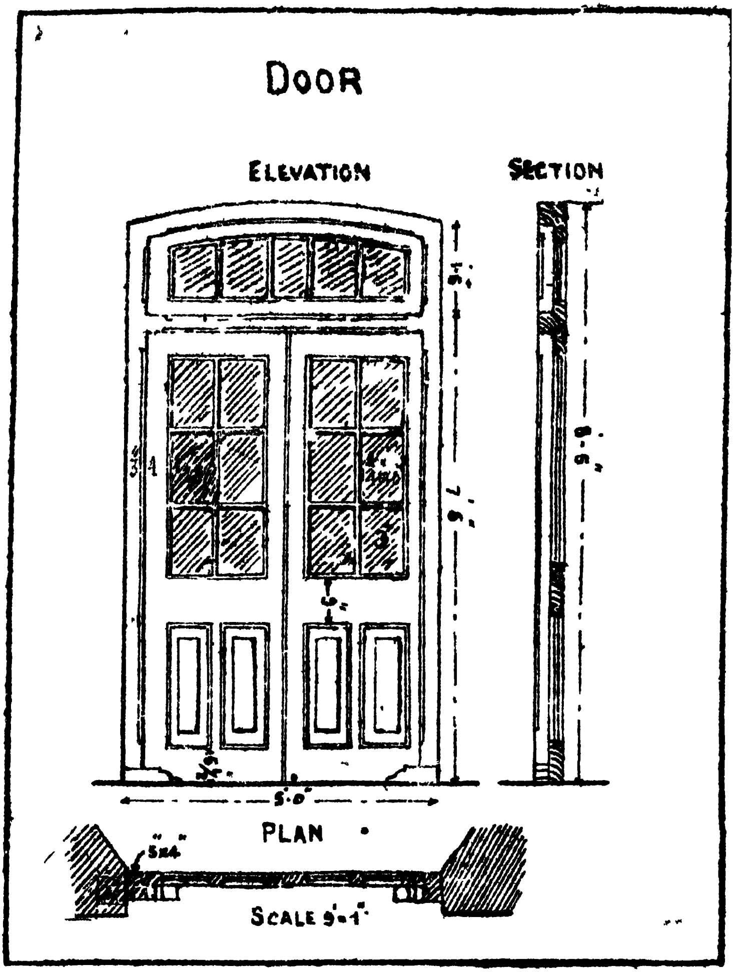

DOOR
ELEVATION
SECTION ON A.B.
SECTION ON C.D
4' · 3"
SCALE 3'=1"
5"x4"

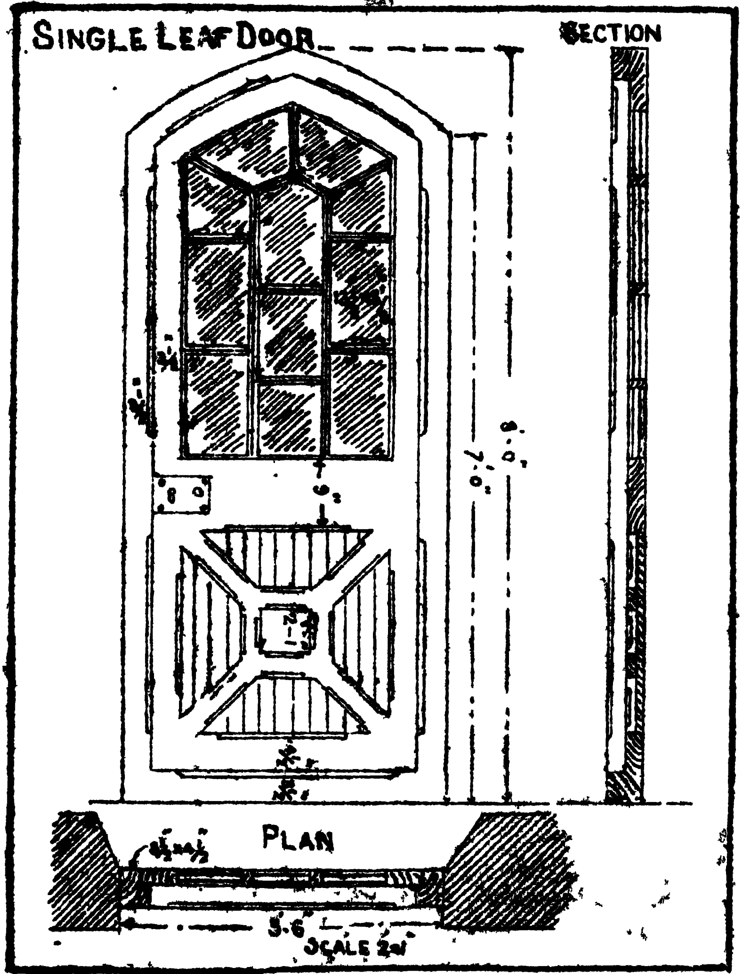

ELEVATION
DOOR
Scale 2"=1'
PLAN
15x10
15x10
7-0
3-2
3-6
3-6
8"
6"
6"
2'

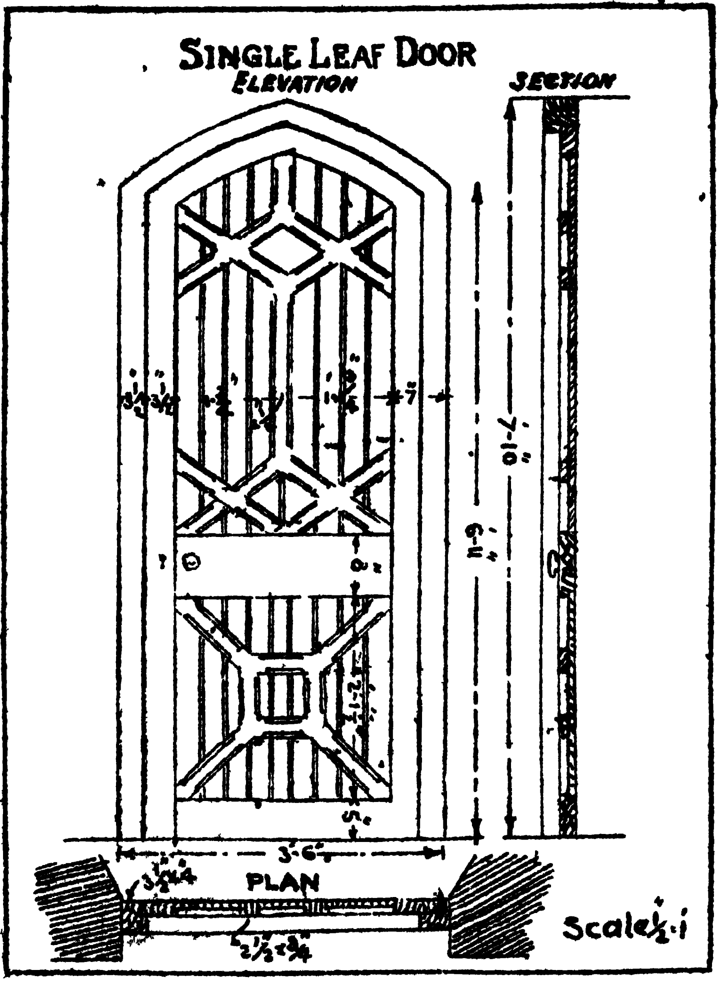

ELEVATION
TOP RAIL
LOCK RAIL
BOTTOM RAIL
3.2
PLAN
DOOR

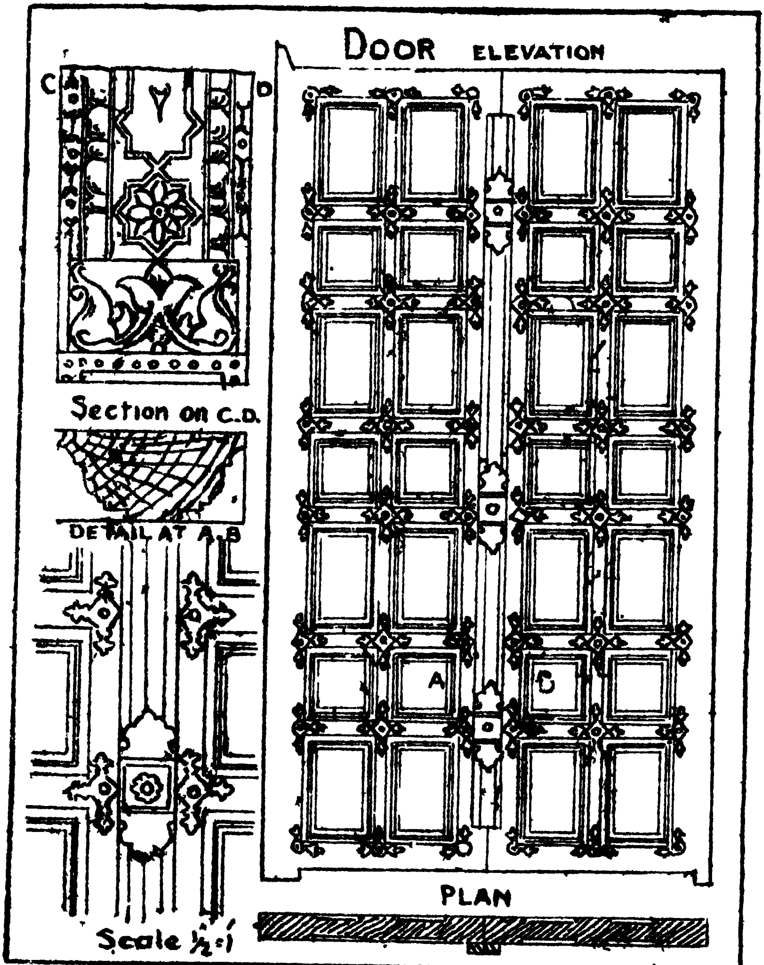

DOOR
ELEVATION
A
SECTION ON A.A.
Glass
Putty
Glass
Glass
B
C
7-6
10
External
Internal
SECTION ON B.C
3-6
Scale ½=1

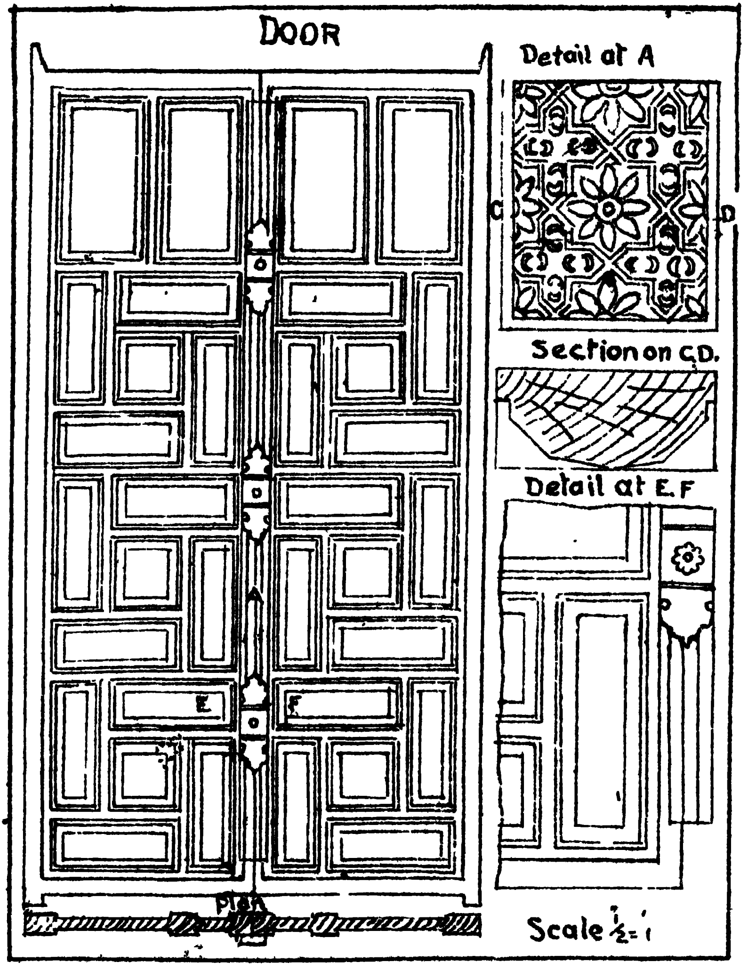

DOOR
External
Internal
PLAN
3-0"
Scale

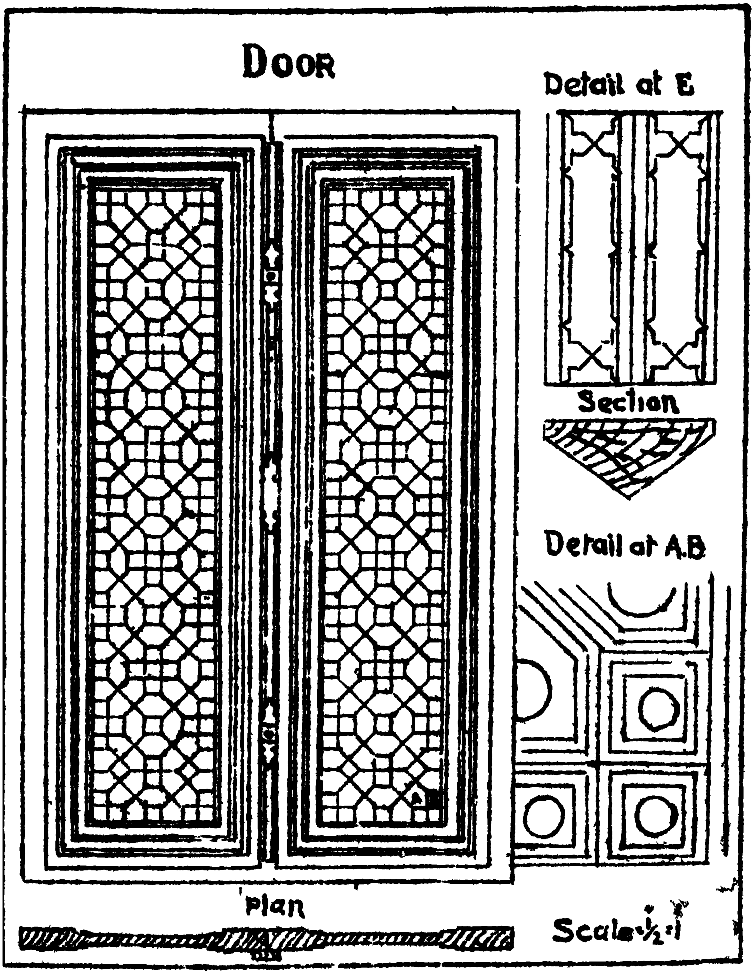

DOOR
ELEVATION
SECTION
5·0"
PLAN
SCALE 9'=1"


SINGLE LEAF DOOR
SECTION
PLAN
5.6
SCALE

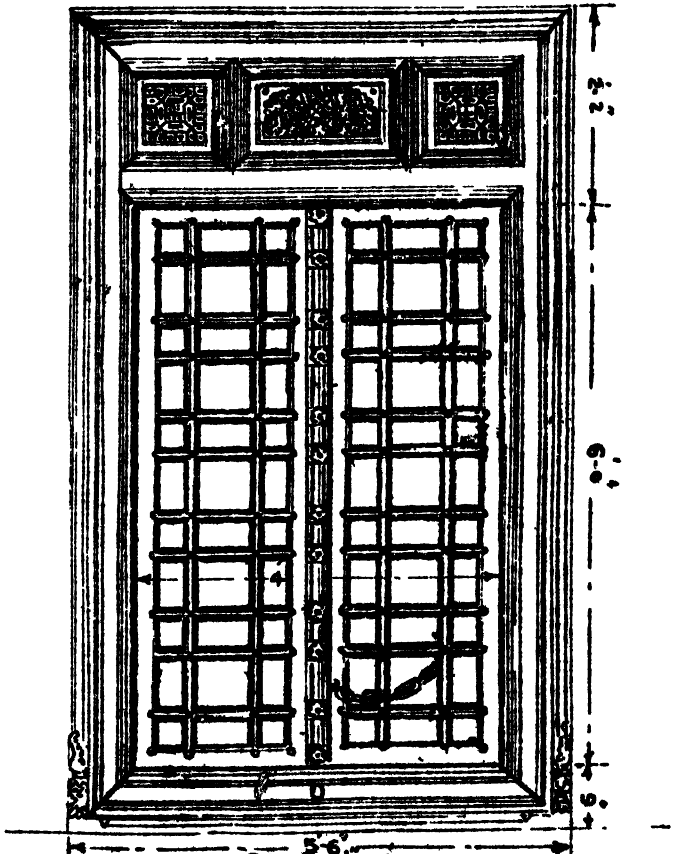

SINGLE LEAF DOOR
ELEVATION
SECTION
7'-10"
6'-11"
3'-6"
PLAN
Scale ½"-1'


DOOR ELEVATION
C
D
Section on C.D.
DETAIL AT A.B
A
B
PLAN
Scale ½=1

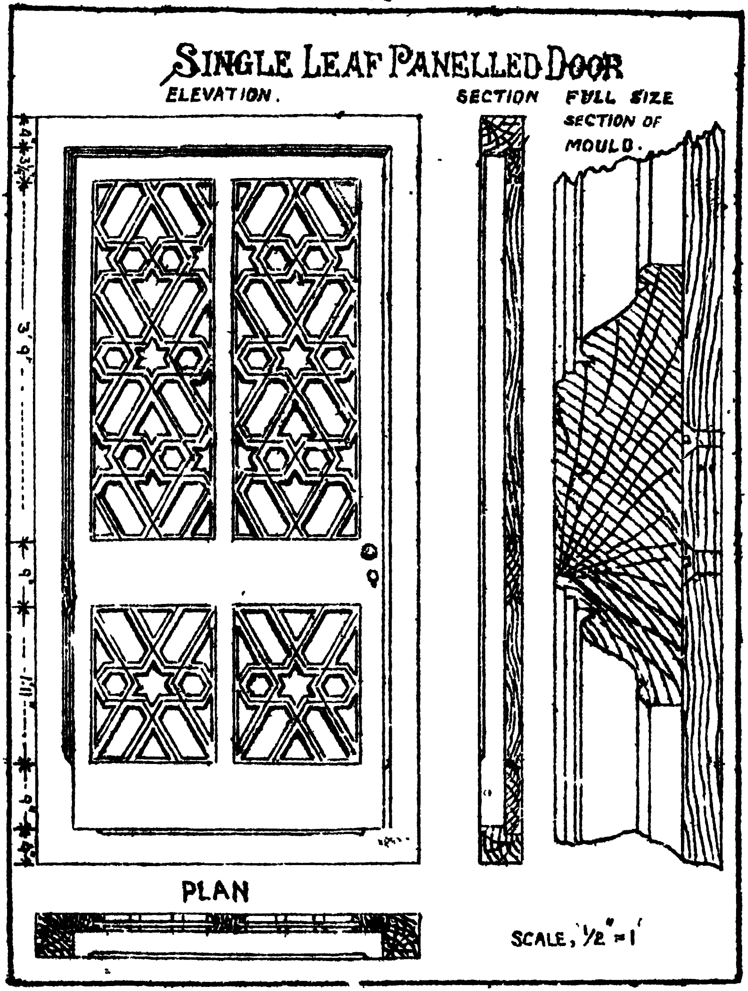

DOOR
Detail at A
C
D
Section on C.D.
Detail at E.F
A
E
F
Plan
Scale ½ = 1

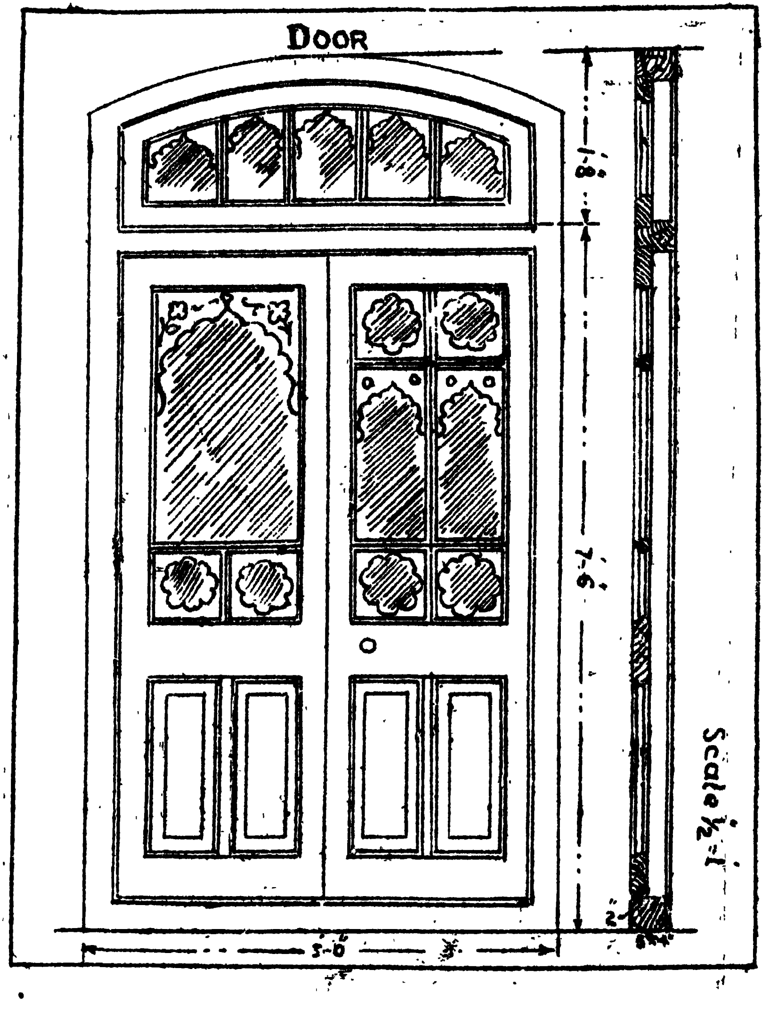

Door
Detail at E
Section
Detail at A.B
Plan
Scale ½:1

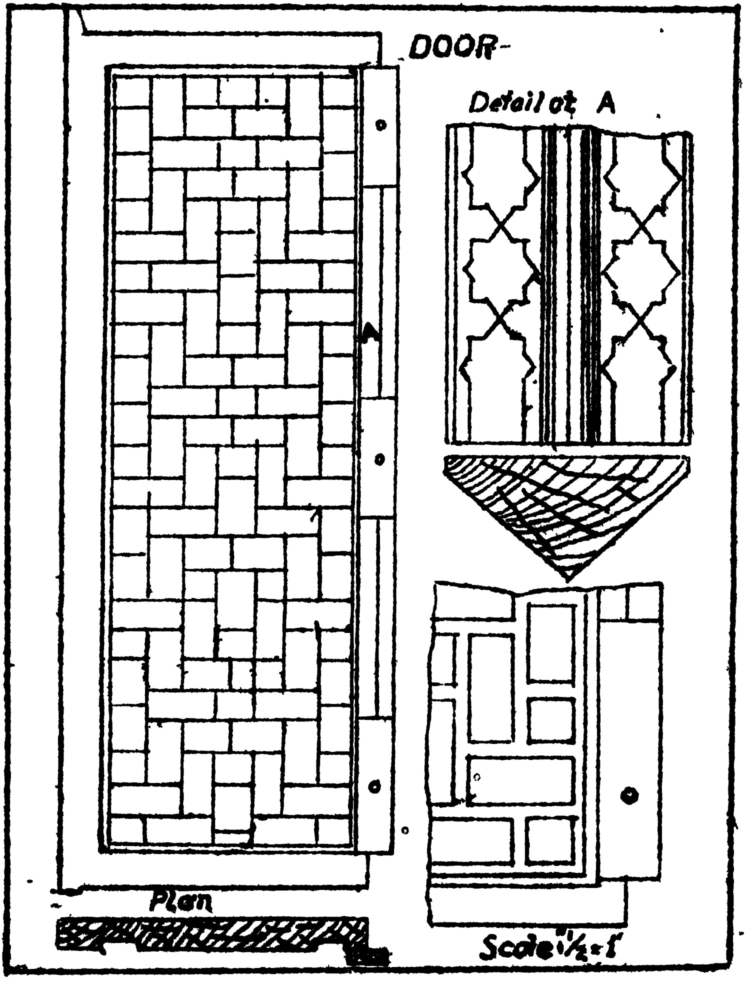
Door



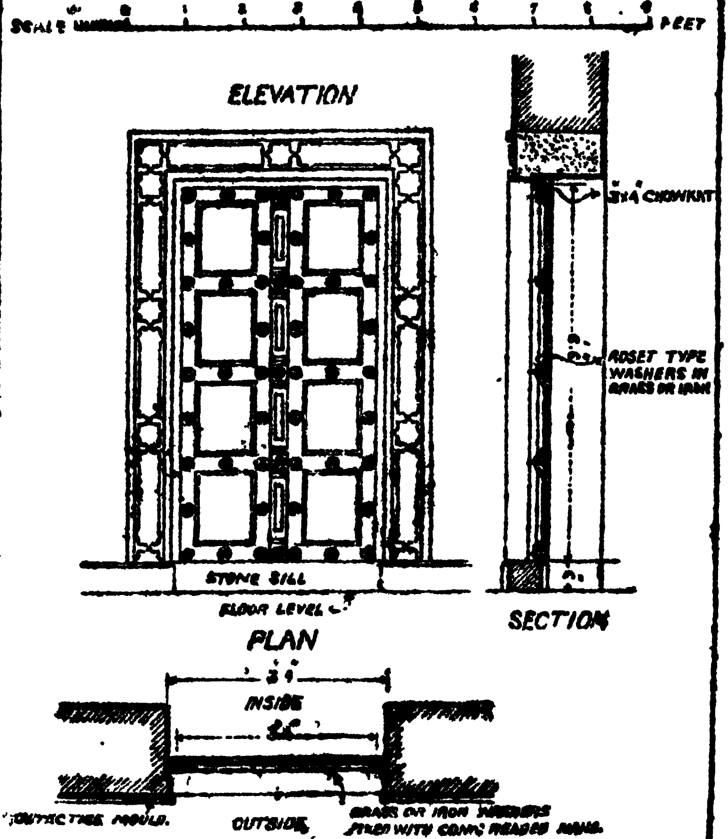
Scale: ½ = 1


SINGLE LEAF PANELLED DOOR
ELEVATION.
SECTION
FULL SIZE SECTION OF MOULD.
3' 9"
9"
PLAN
SCALE, ½" = 1'

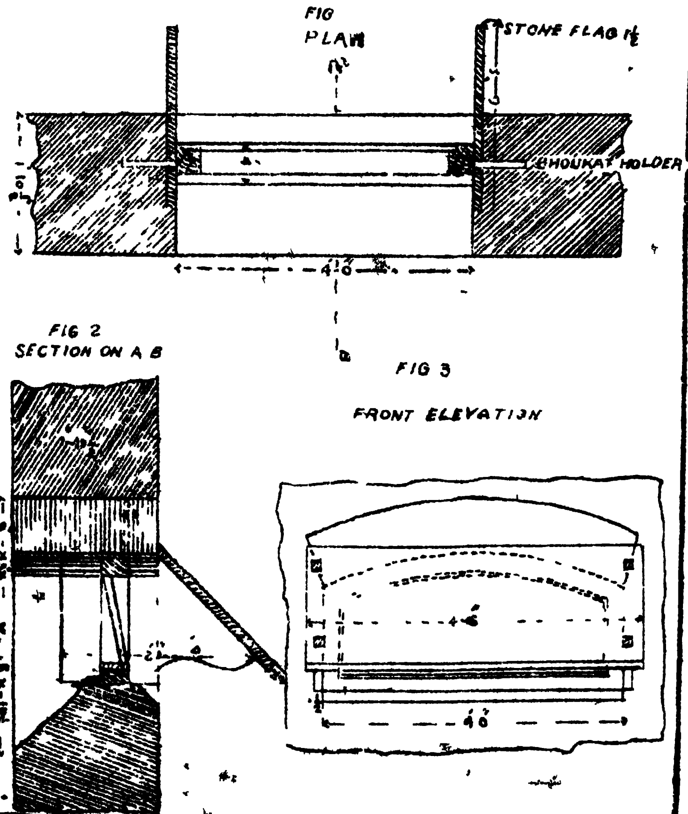

Door
1-8"
7-6"
3-0"
2"
Scale ½"=1'


DOOR
Detail at A
A
Plan
Scale 1½ = 1'

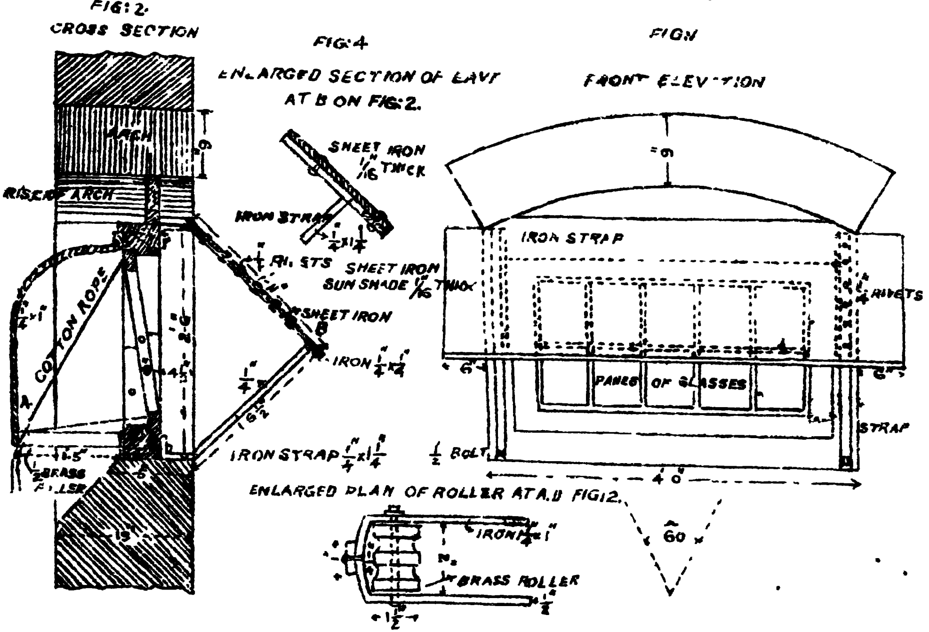
ENTRANCE DOOR OF INDIAN STYLE.

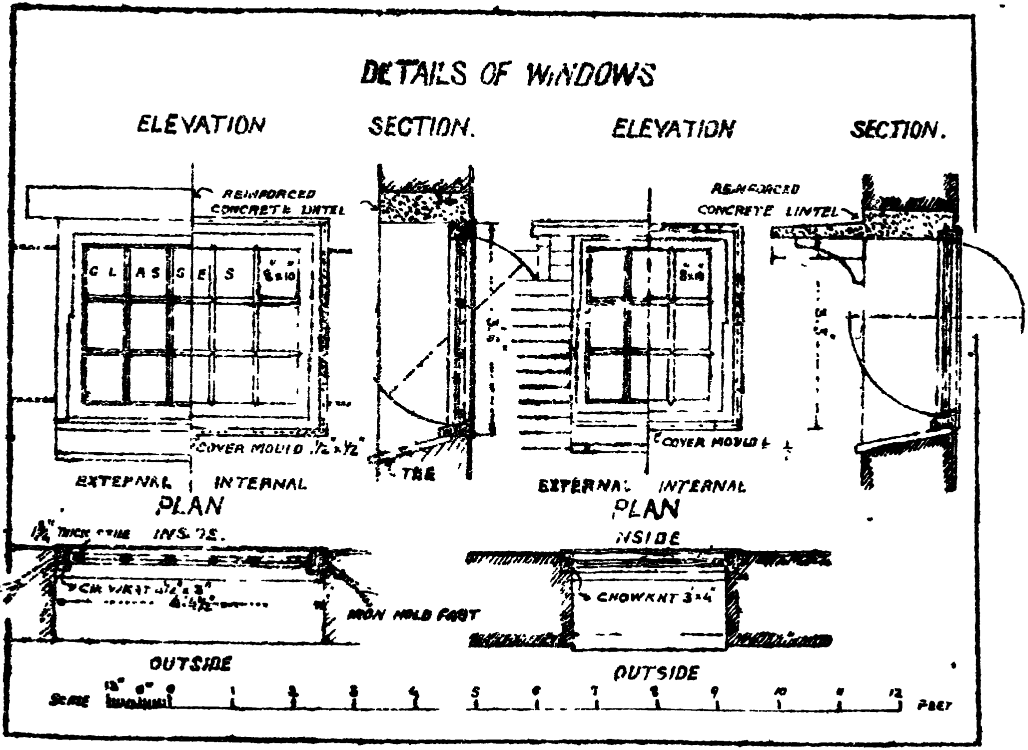


VENTILATOR

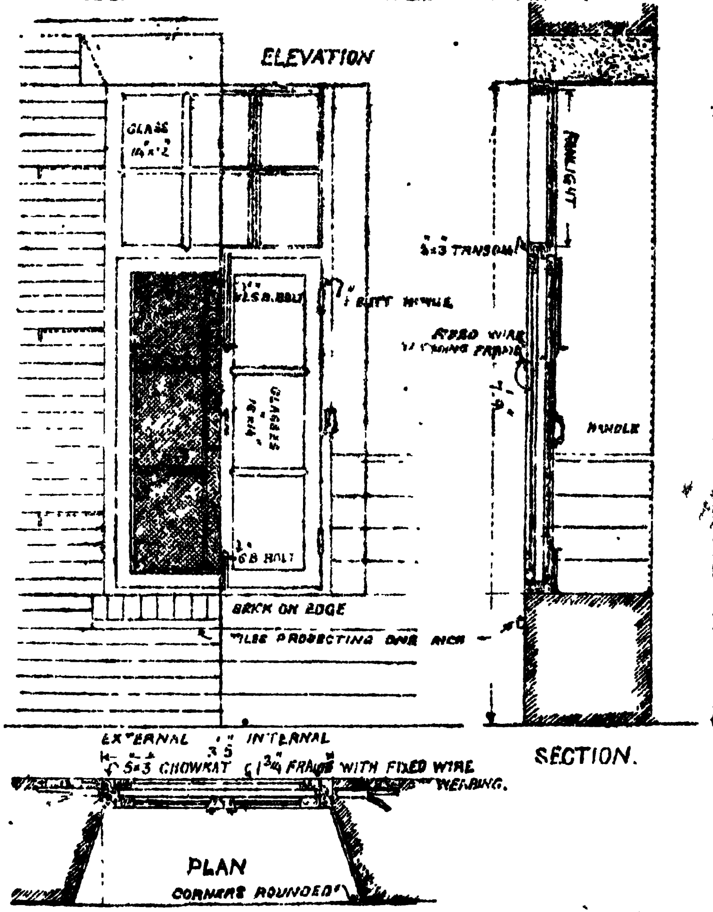

FIG
PLAN
STONE FLAG 1½
CHOUKAT HOLDER
4' 0"
FIG 2
SECTION ON A B
FIG 3
FRONT ELEVATION
4' 0"

VENTILATOR WITH SUNSHADE

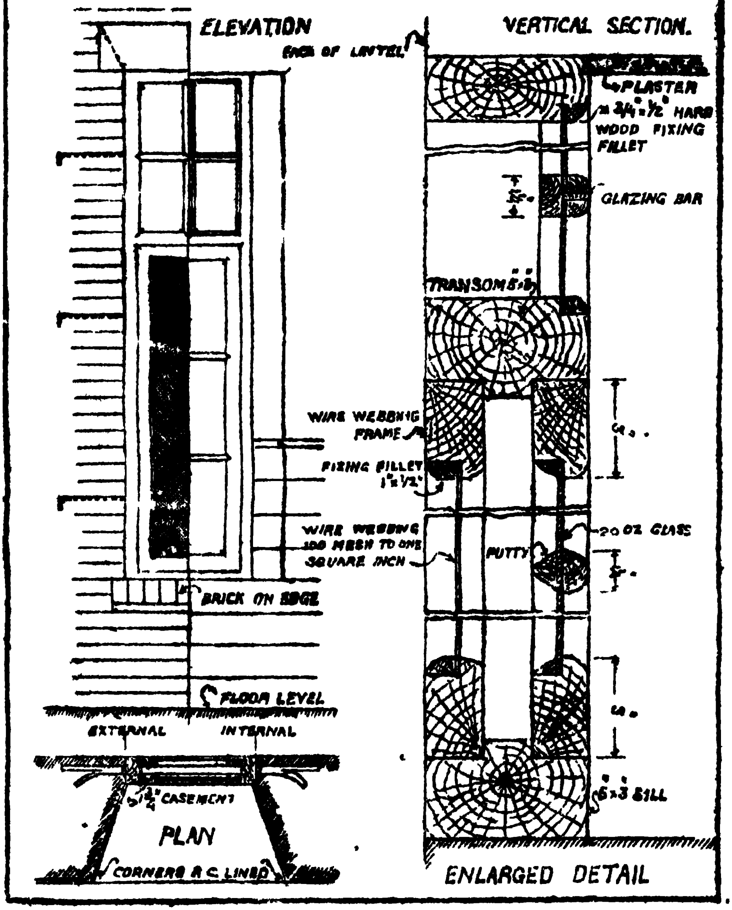



DETAILS OF WINDOWS
ELEVATION
SECTION.
ELEVATION
SECTION.
REINFORCED
CONCRETE LINTEL
GLASSES
COVER MOULD
EXTERNAL
INTERNAL
PLAN
INSIDE
IRON HOLD FAST
OUTSIDE
SCALE
FEET

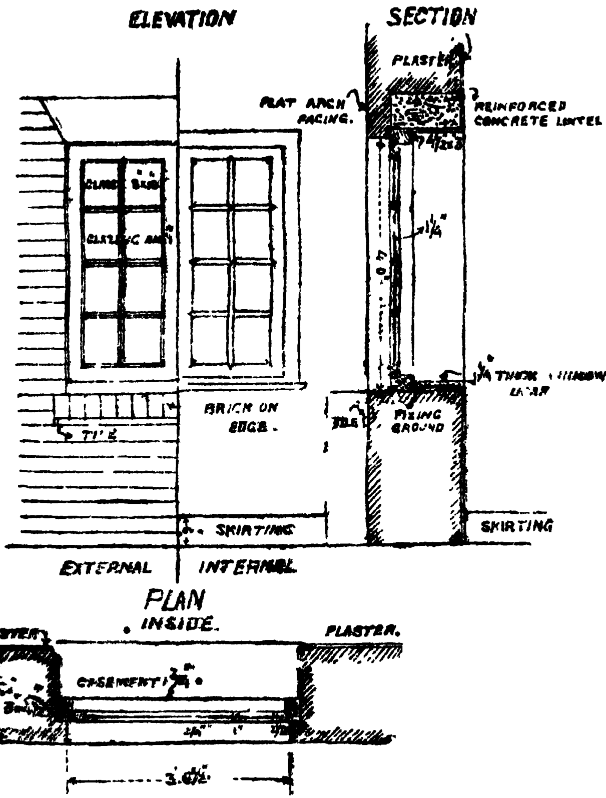
HOSPITAL WINDOW WITH FIXED FANLIGHT.

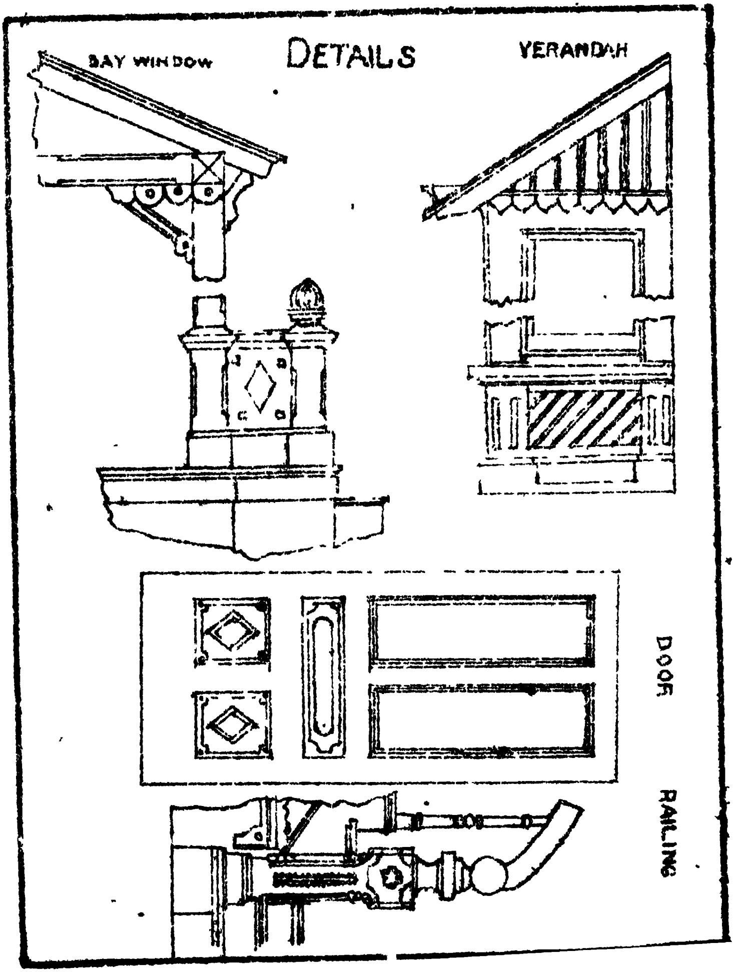


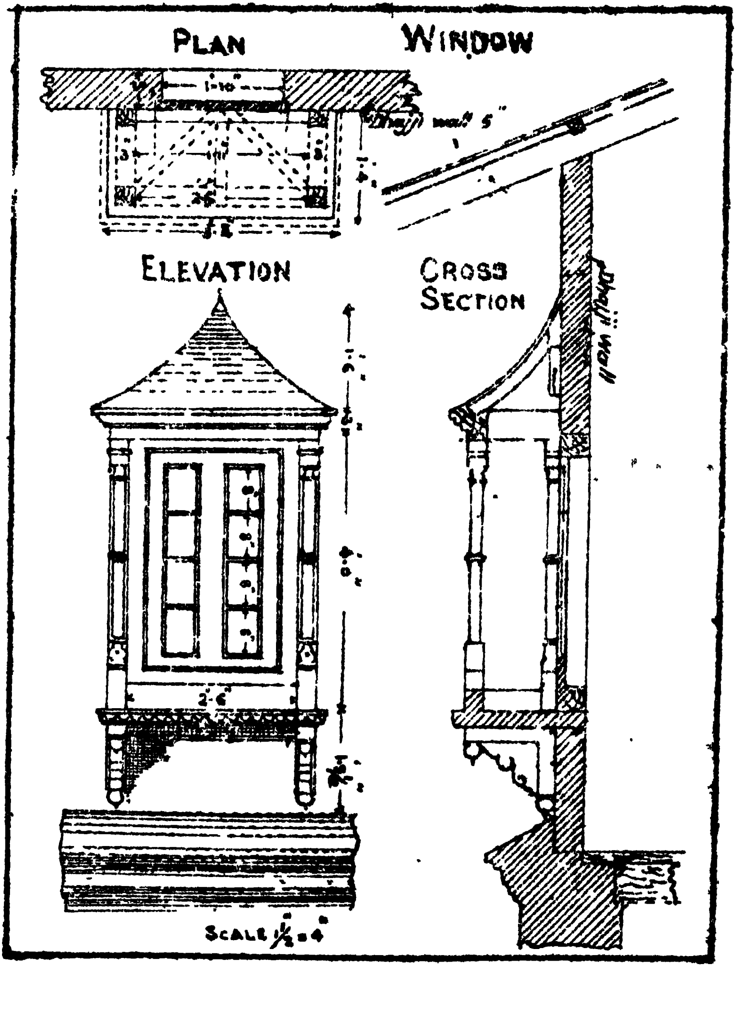
NARROW WINDOW AT ENDS OF HOSPITAL WARDS.

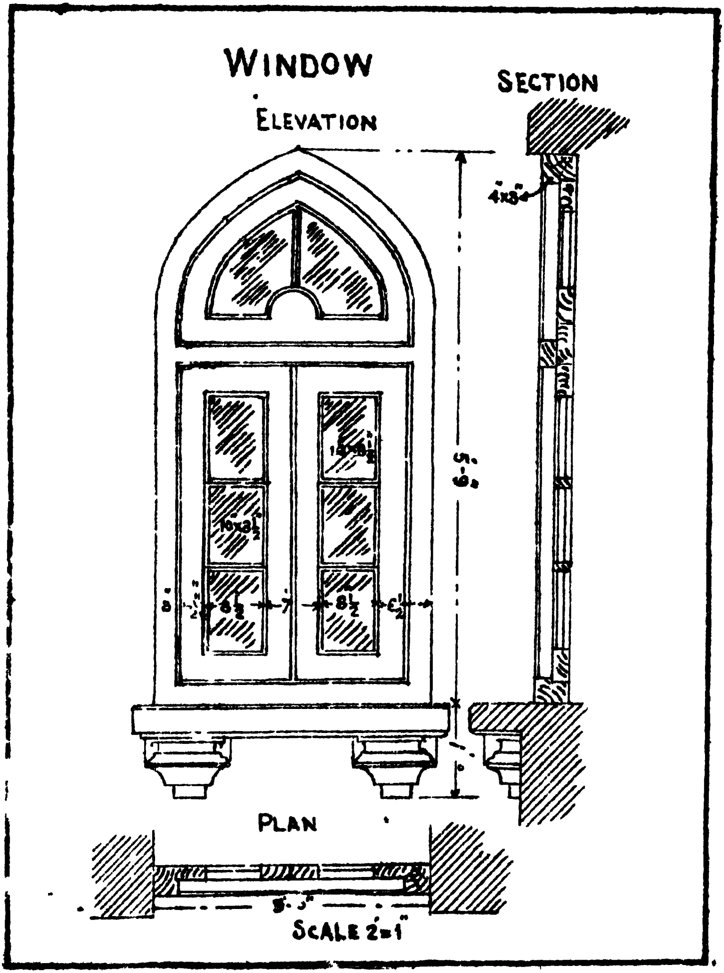


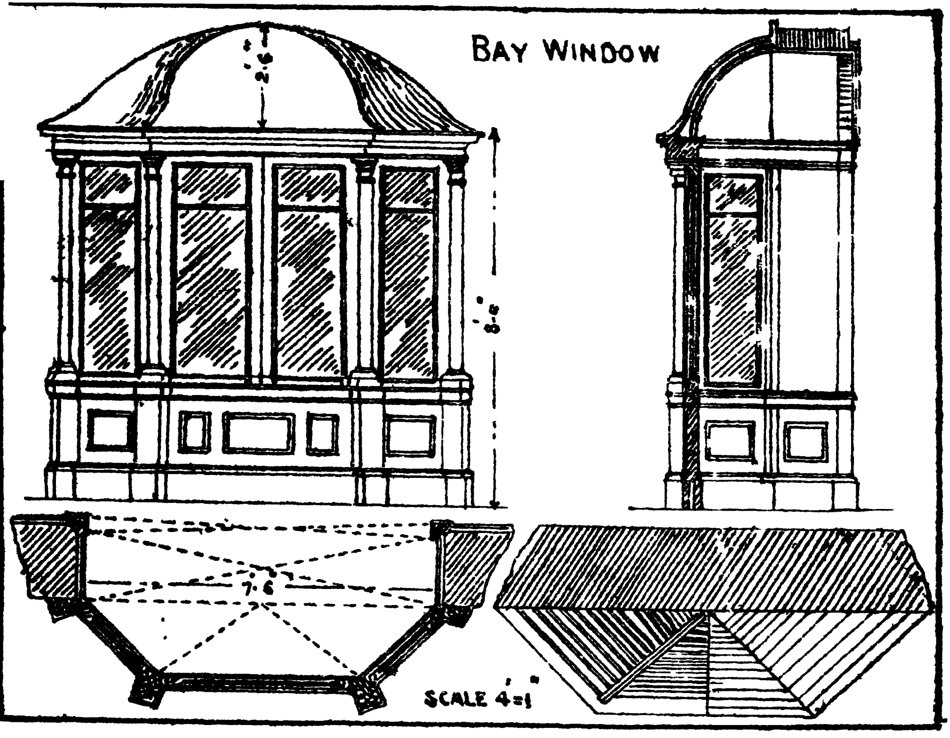
DETAILS OF WINDOW

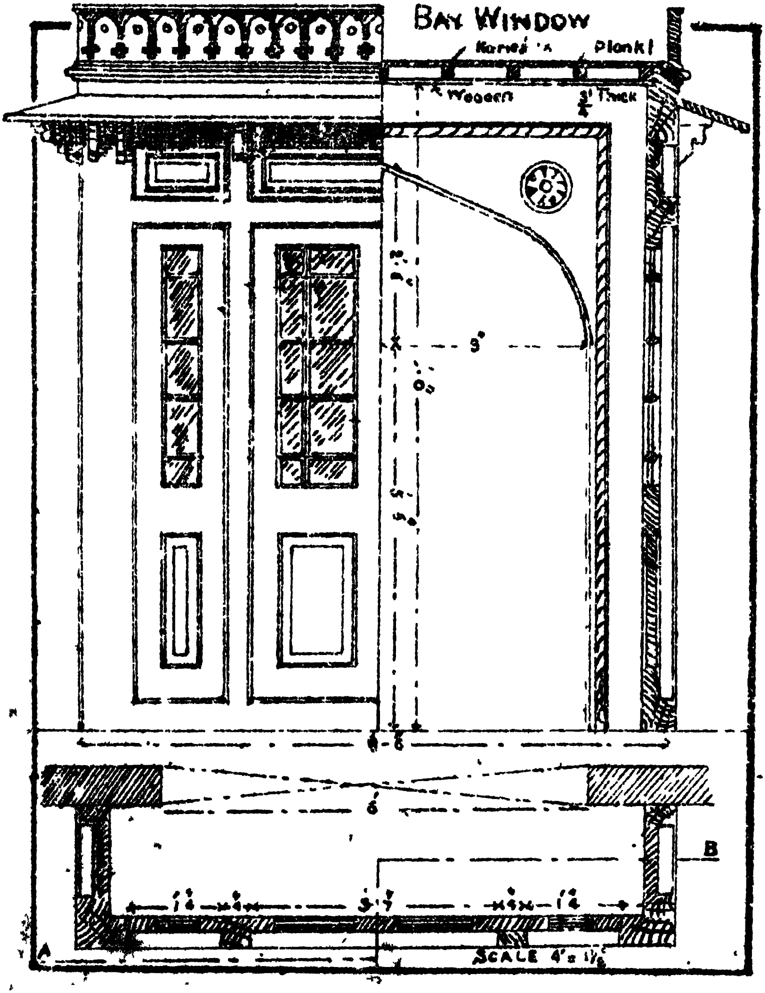


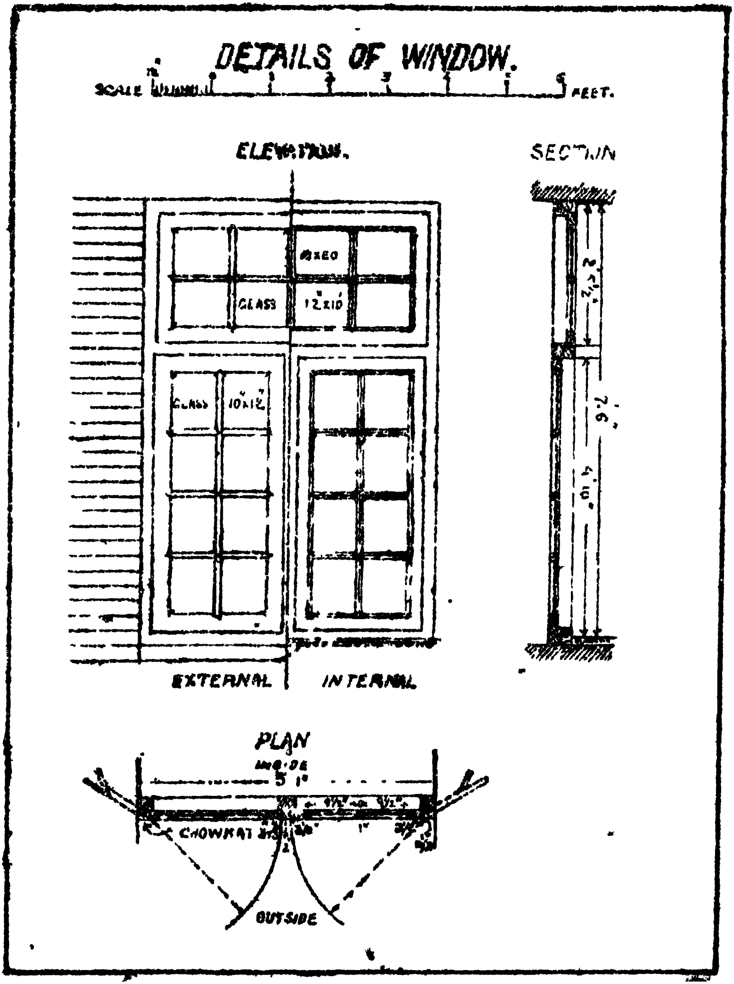

DETAILS
BAY WINDOW
VERANDAH
DOOR
RAILING

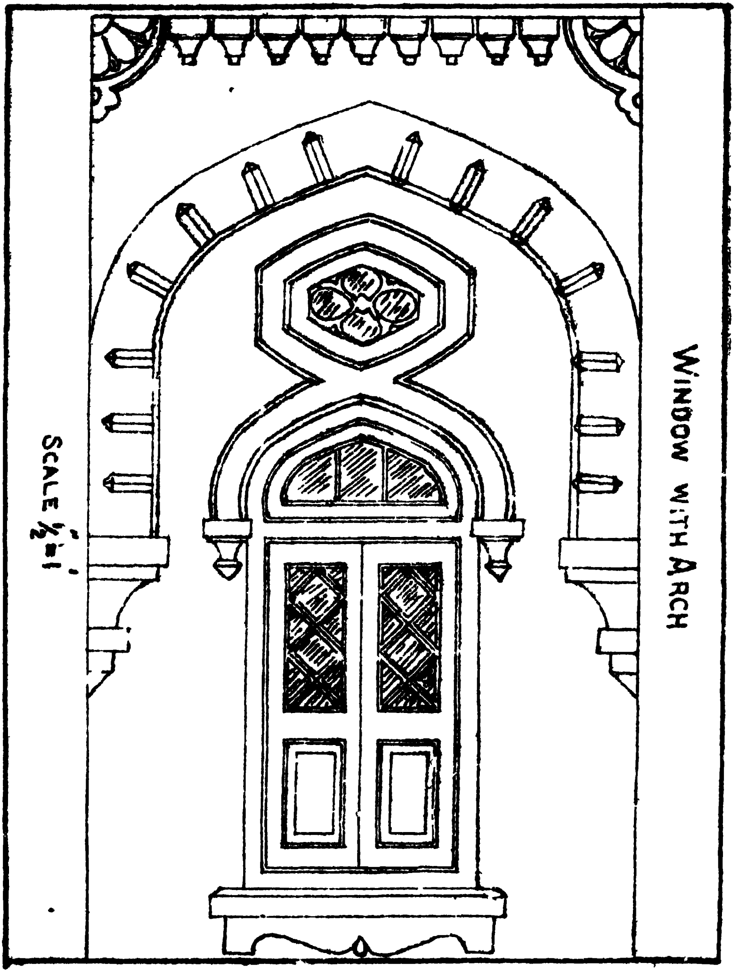

PLAN
WINDOW
ELEVATION
CROSS SECTION
SCALE ½" = 4"

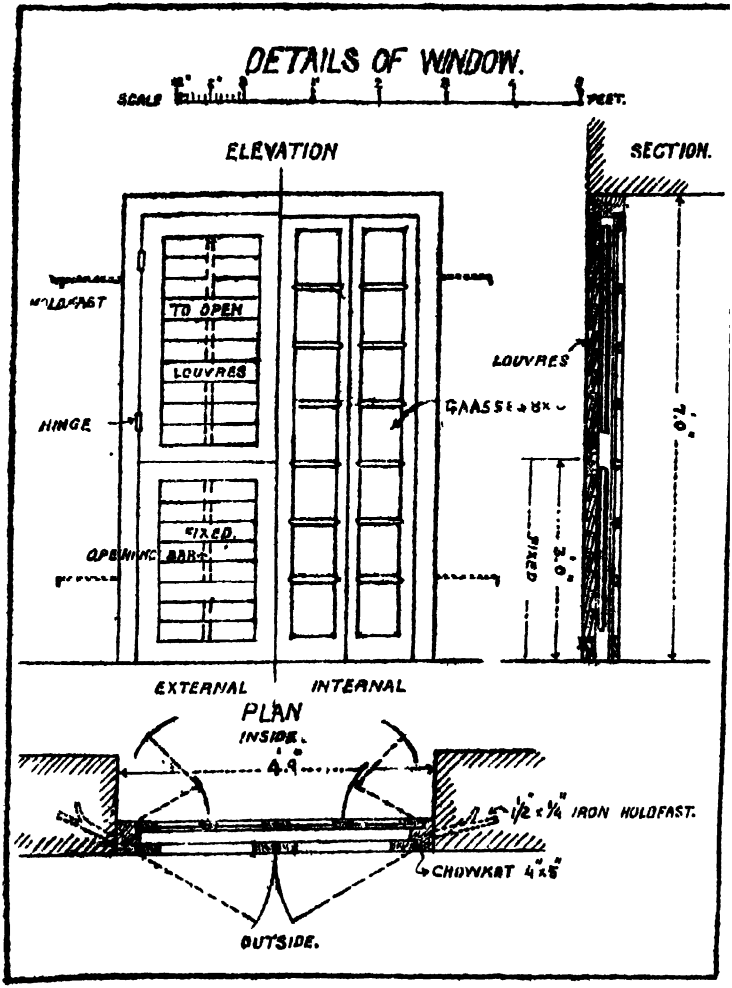

WINDOW
SECTION
ELEVATION
PLAN
SCALE 2'=1"


BAY WINDOW
2' 6"
8' 6"
7' 6"
SCALE 4'=1"

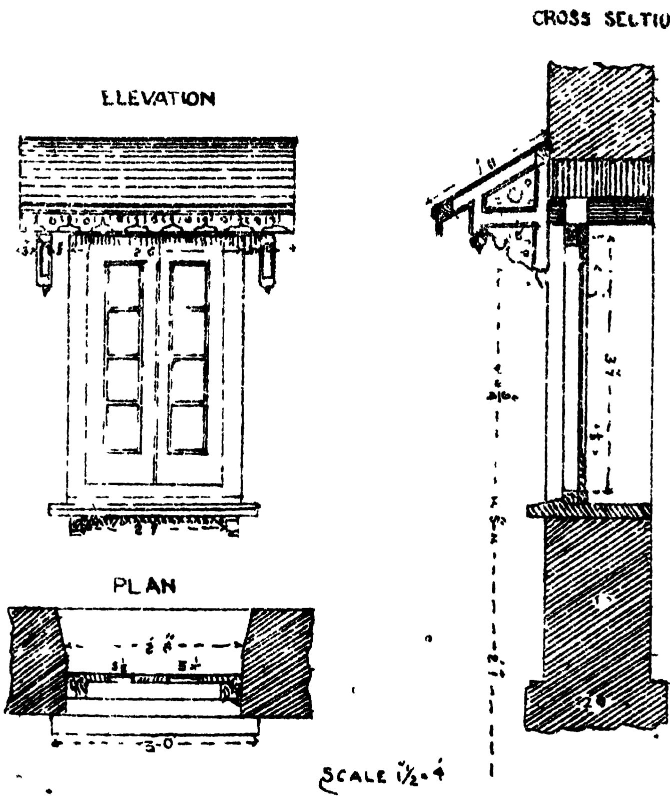

BAY WINDOW
Plank
Thick
B
A
SCALE


DETAILS OF WINDOW.
SCALE
FEET.
ELEVATION.
SECTION
GLASS
12"x10"
GLASS
10"x12"
EXTERNAL
INTERNAL
7'6"
4'10"
PLAN
INSIDE
5' 1"
CHOWKAT
OUTSIDE

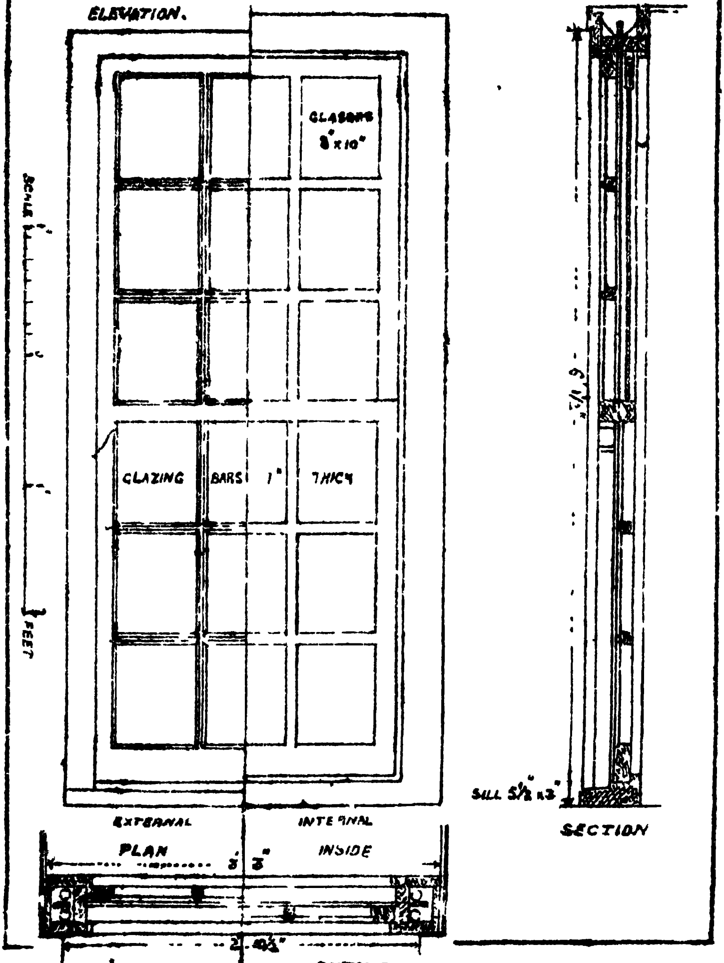

WINDOW WITH ARCH
SCALE ½" = 1'

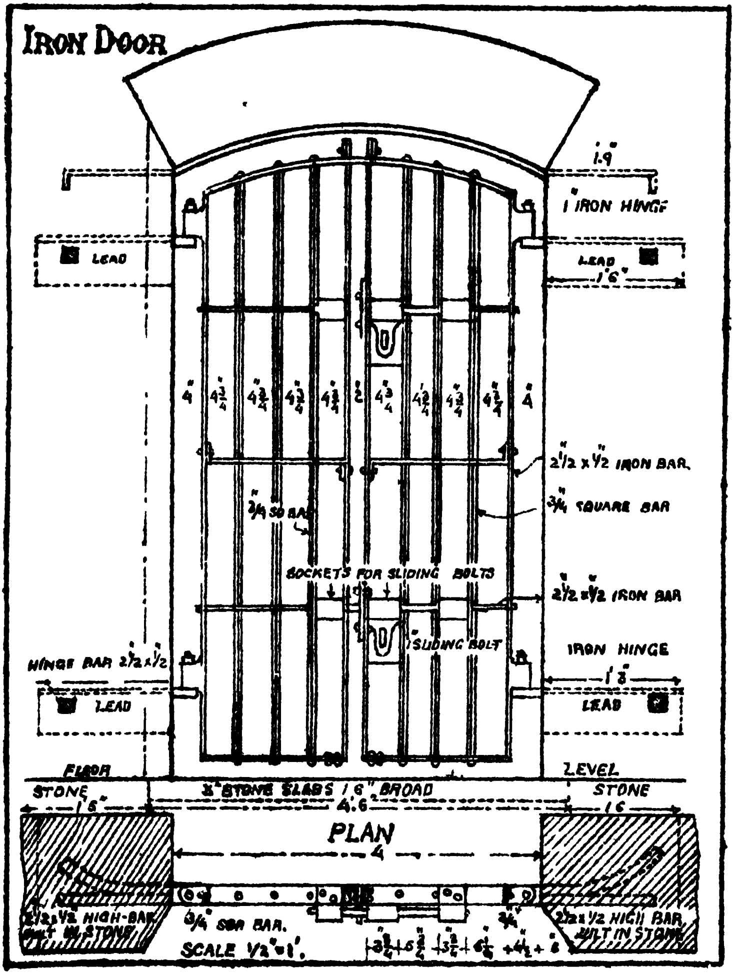

DETAILS OF WINDOW.
SCALE
FEET.
ELEVATION
SECTION.
TO OPEN
LOUVRES
HINGE
FIXED.
LOUVRES
FIXED
3.0"
7.0"
EXTERNAL
INTERNAL
PLAN
INSIDE.
4.9"
1/2" x 1/4" IRON HOLDFAST.
CHOWKAT 4" x 5"
OUTSIDE.

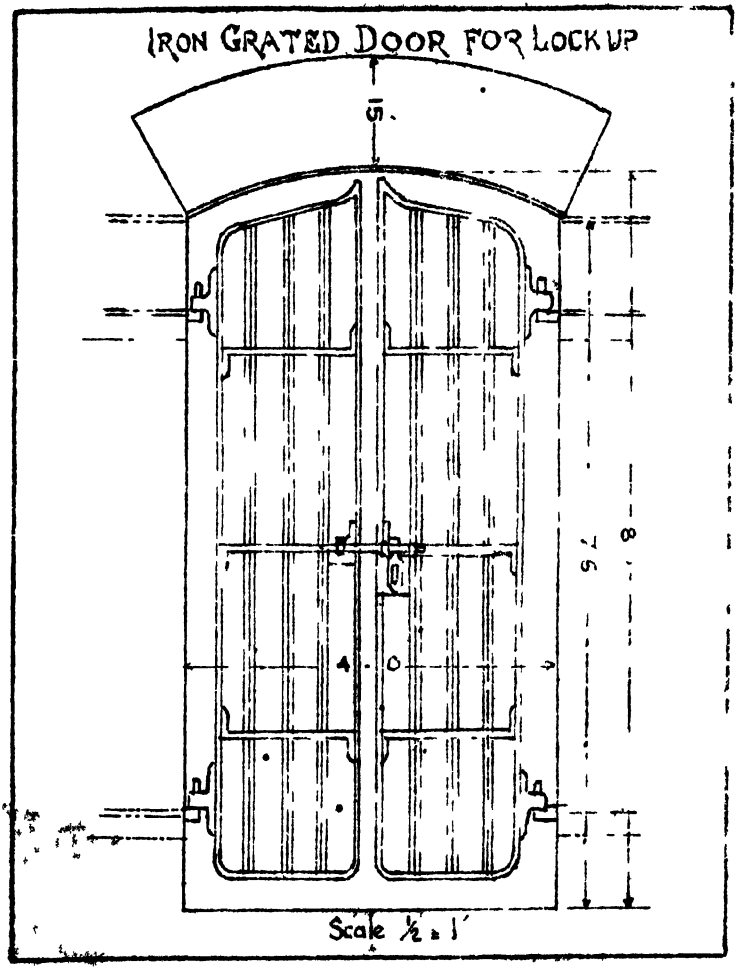
WINDOW

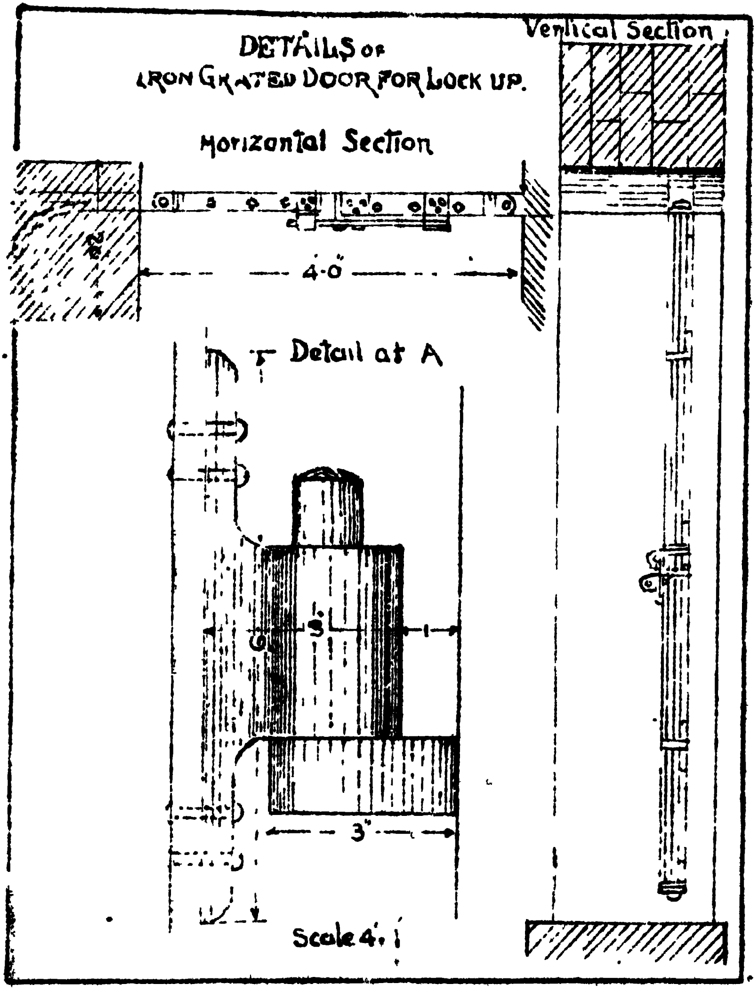


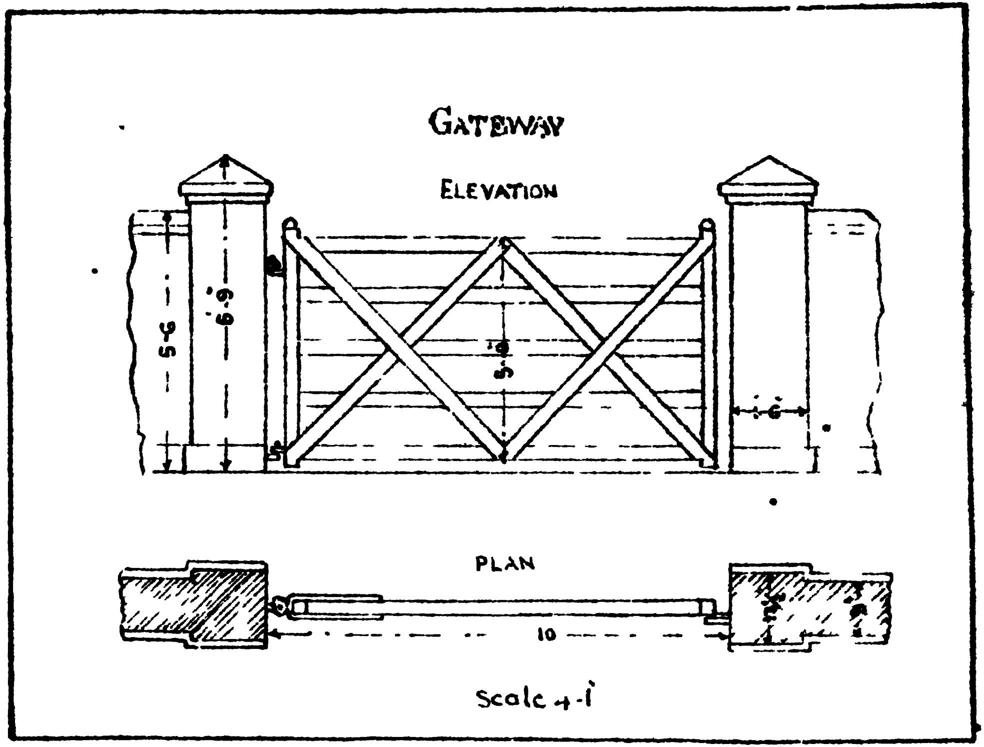
DETAILS OF WINDOW

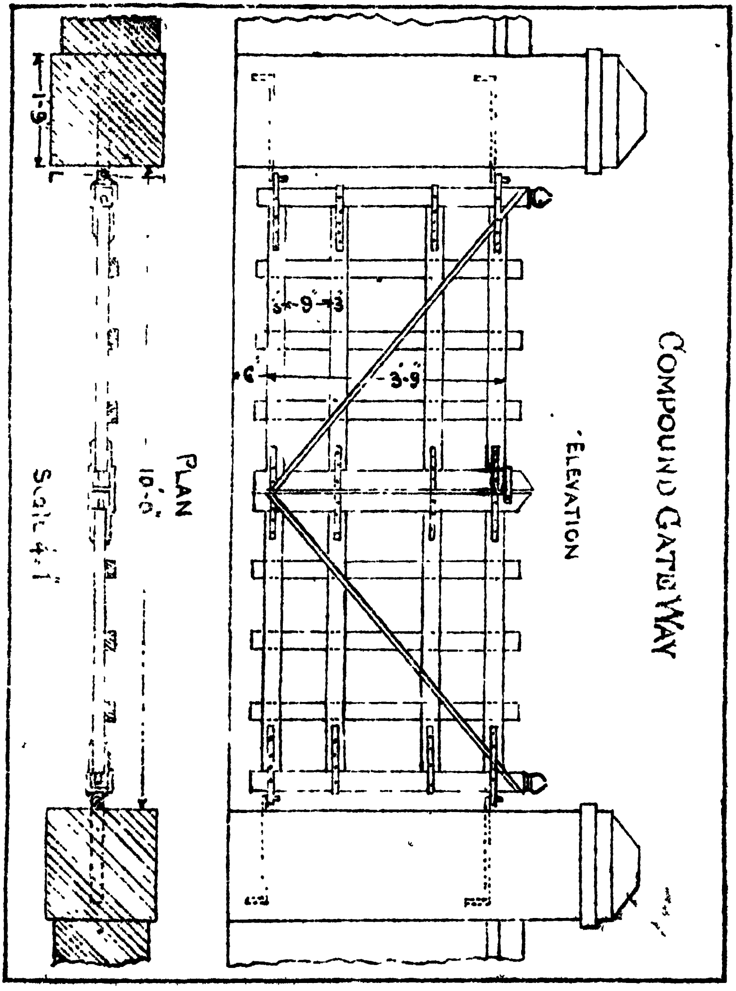


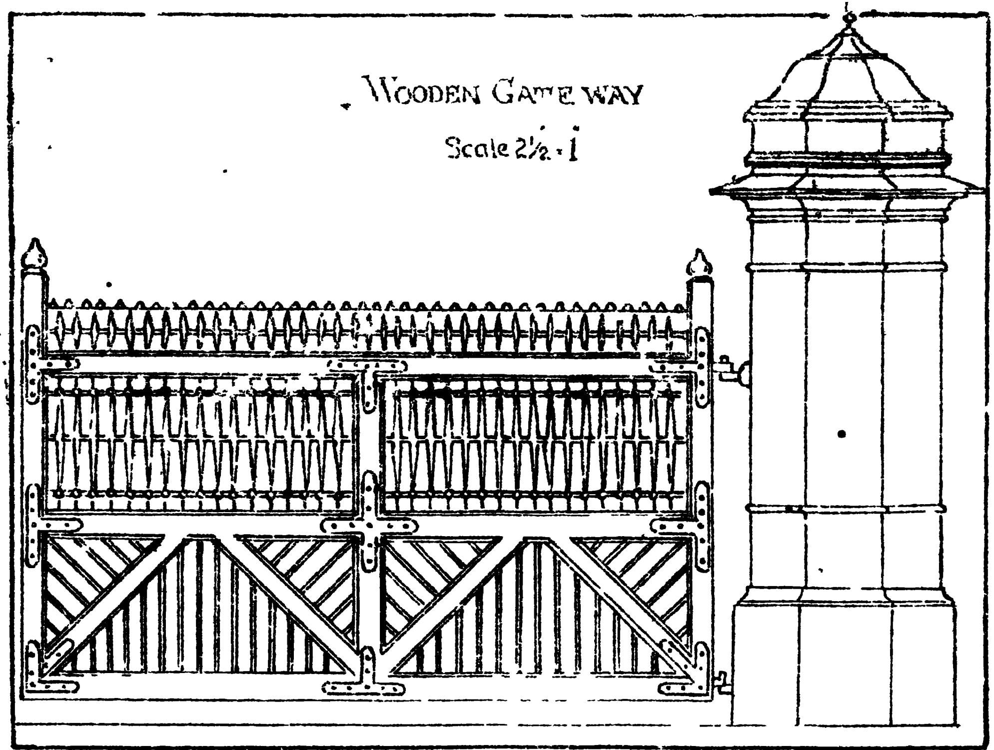

IRON DOOR
1.9"
1" IRON HINGE
LEAD
LEAD
1'6"
2½" x ½" IRON BAR
¾" SQUARE BAR
¾" SQ BAR
SOCKETS FOR SLIDING BOLTS
2½" x ½" IRON BAR
SLIDING BOLT
IRON HINGE
HINGE BAR 2½" x ½"
1'3"
LEAD
LEAD
FLOOR
LEVEL
STONE
STONE
STONE SLABS 1'6" BROAD
1'6"
4'6
1'6
PLAN
4
2½ x ½ HIGH-BAR BUILT IN STONE
¾" SQR BAR.
2½ x ½ HIGH BAR BUILT IN STONE
SCALE ½" = 1'.

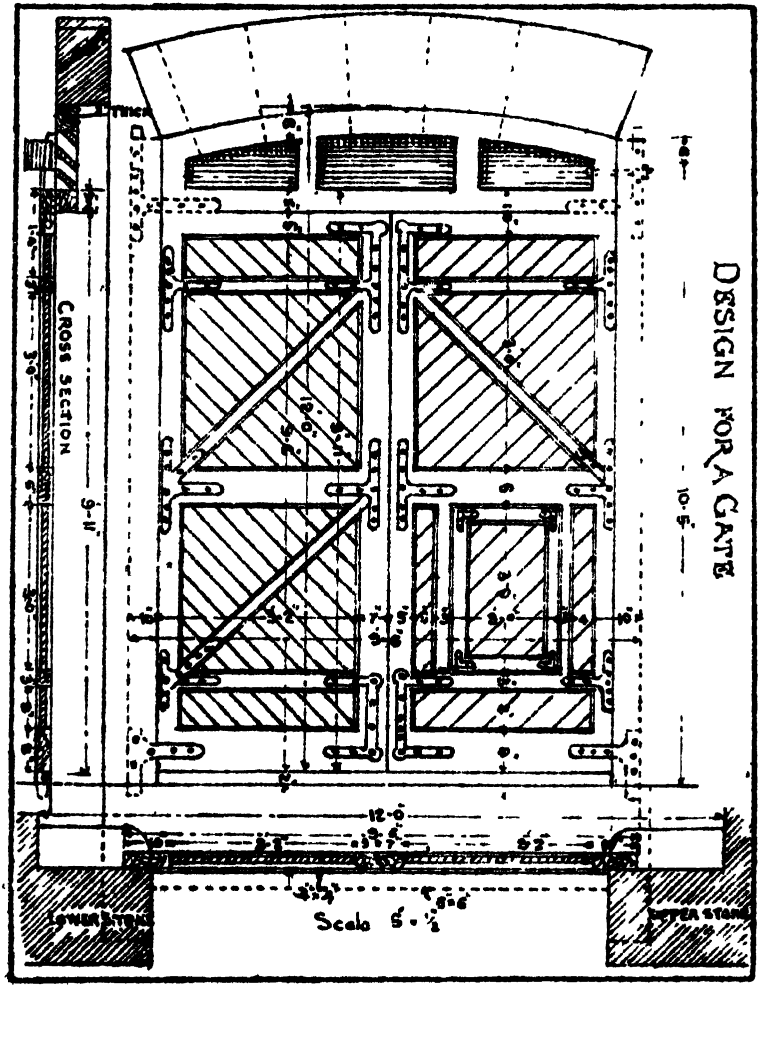

IRON GRATED DOOR FOR LOCK UP
1.5
4.0
7.5
8.1
Scale ½ = 1'


DETAILS OF
IRON GRATED DOOR FOR LOCK UP.
Horizontal Section
Vertical Section
4·0"
Detail at A
5
6
1
3"
Scale 4: 1

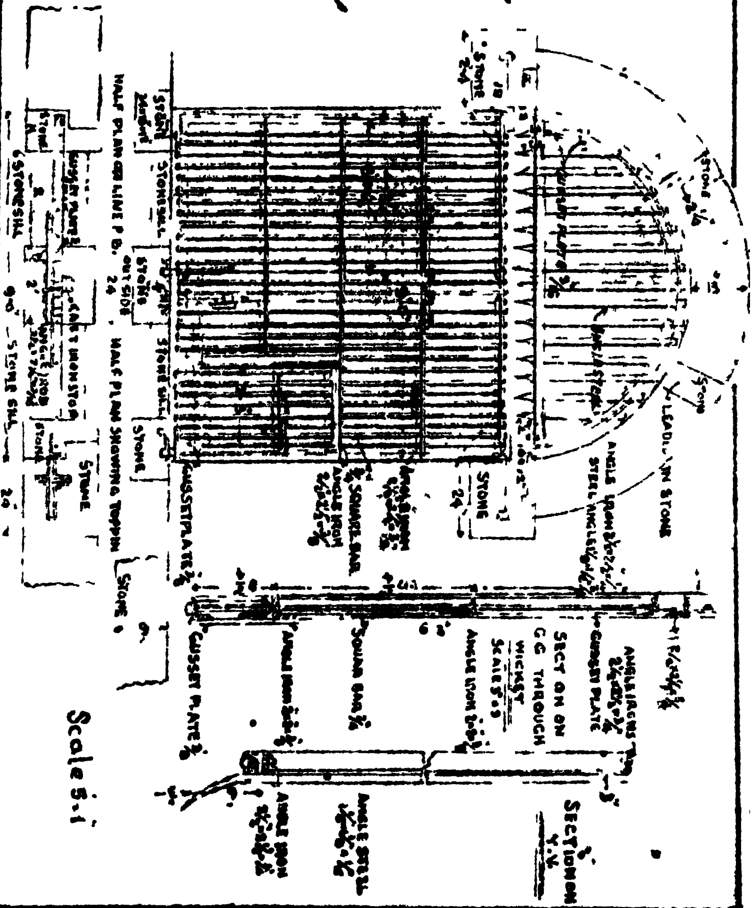

GATEWAY
ELEVATION
5-6
6-9
5-0
1-6
PLAN
10
Scale 4-1'

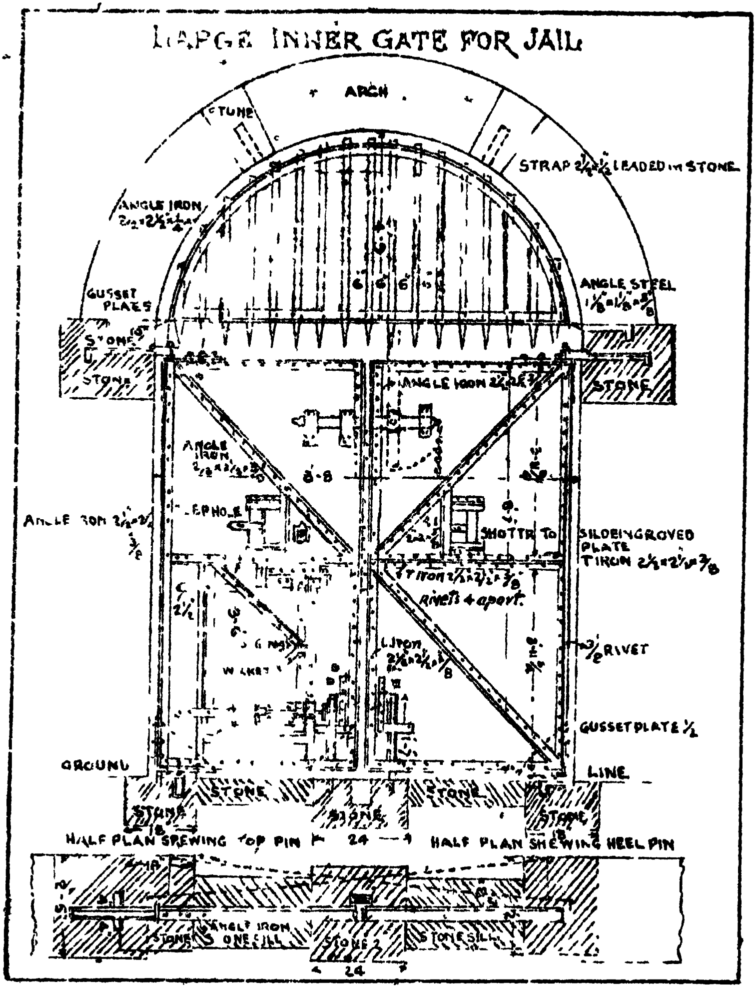

COMPOUND GATE WAY
ELEVATION
PLAN
10'-0"
1'-9"
3'-9"
6"

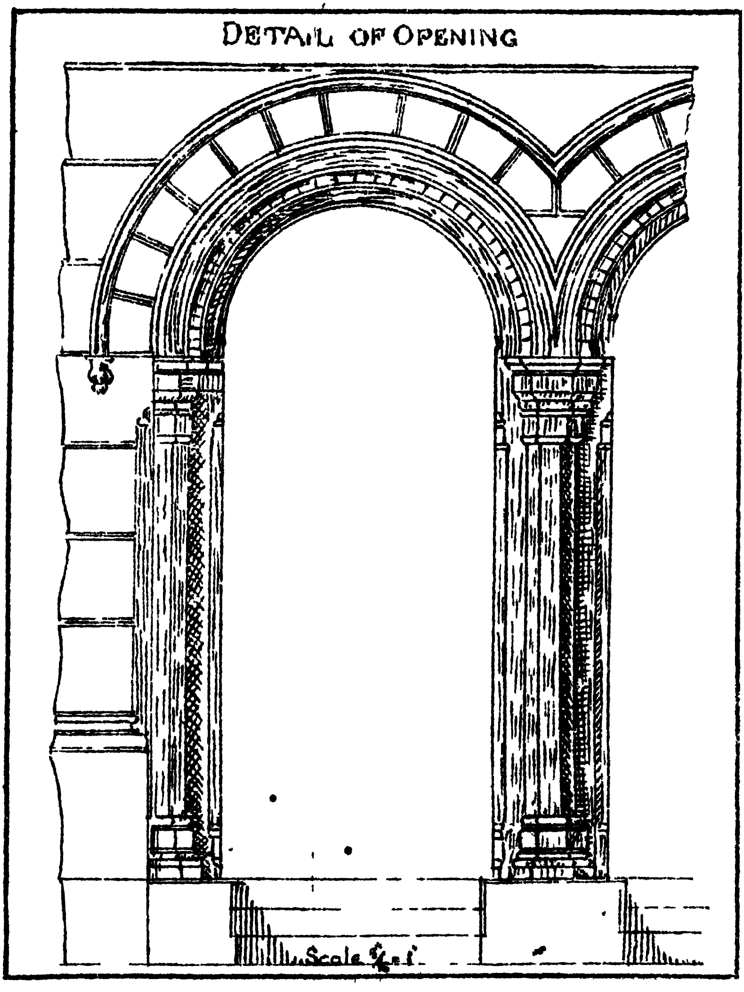

WOODEN GATE WAY
Scale 2½ : 1

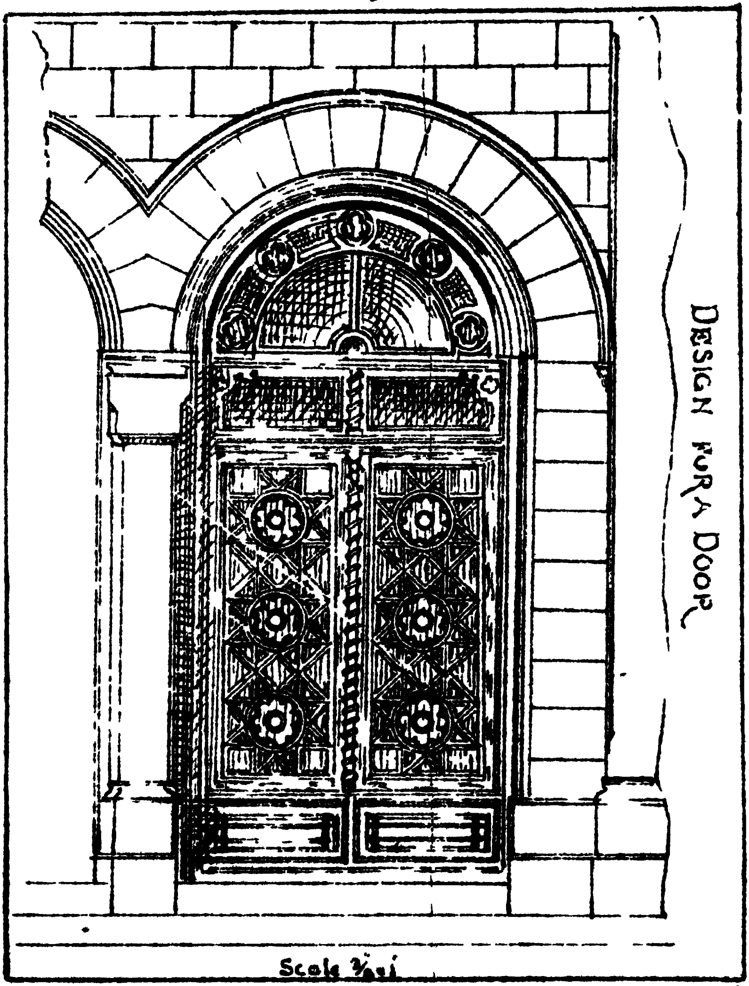

DESIGN FOR A GATE
CROSS SECTION
LOWER STONE
UPPER STONE
Scale 5 - ½

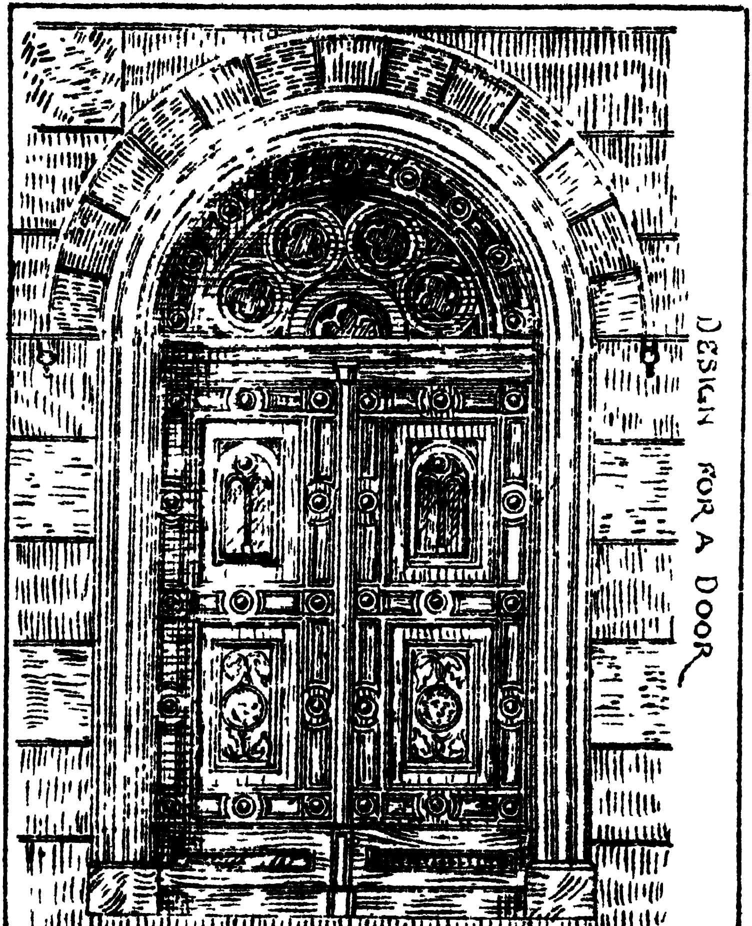
LARGE OUTER GATE FOR JAIL

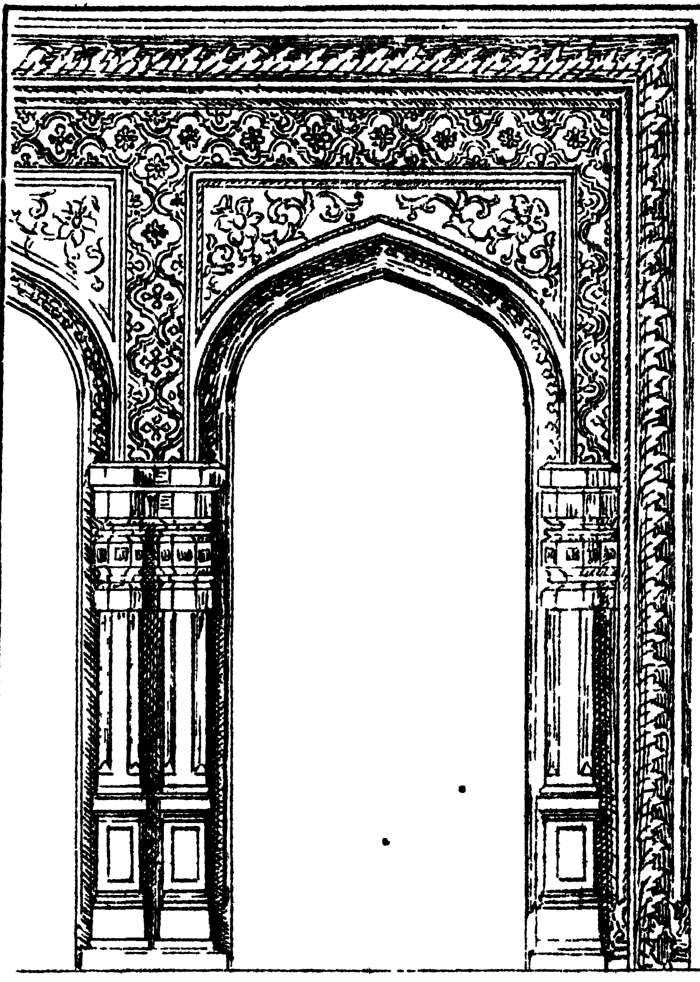



LARGE INNER GATE FOR JAIL
ARCH
STONE
STRAP 2½×½ LEADED IN STONE
ANGLE IRON
GUSSET PLATES
ANGLE STEEL
STONE
ANGLE IRON
RIVETS 4 apart.
½ RIVET
GUSSET PLATE ½
GROUND
LINE
HALF PLAN SHEWING TOP PIN
24
HALF PLAN SHEWING HEEL PIN
ANGLE IRON
STONE SILL
24


DETAIL OF OPENING
Scale

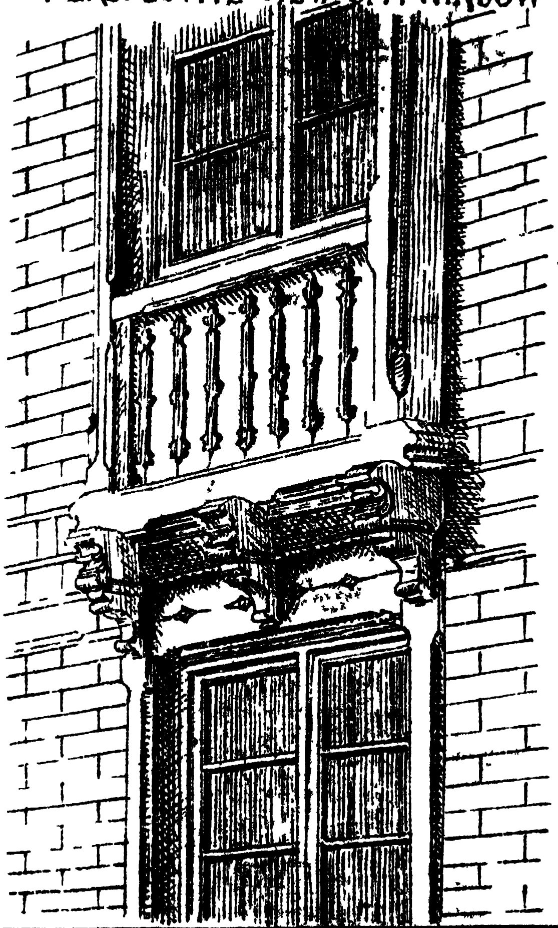

DESIGN FOR A DOOR
Scale 3/4"=1'

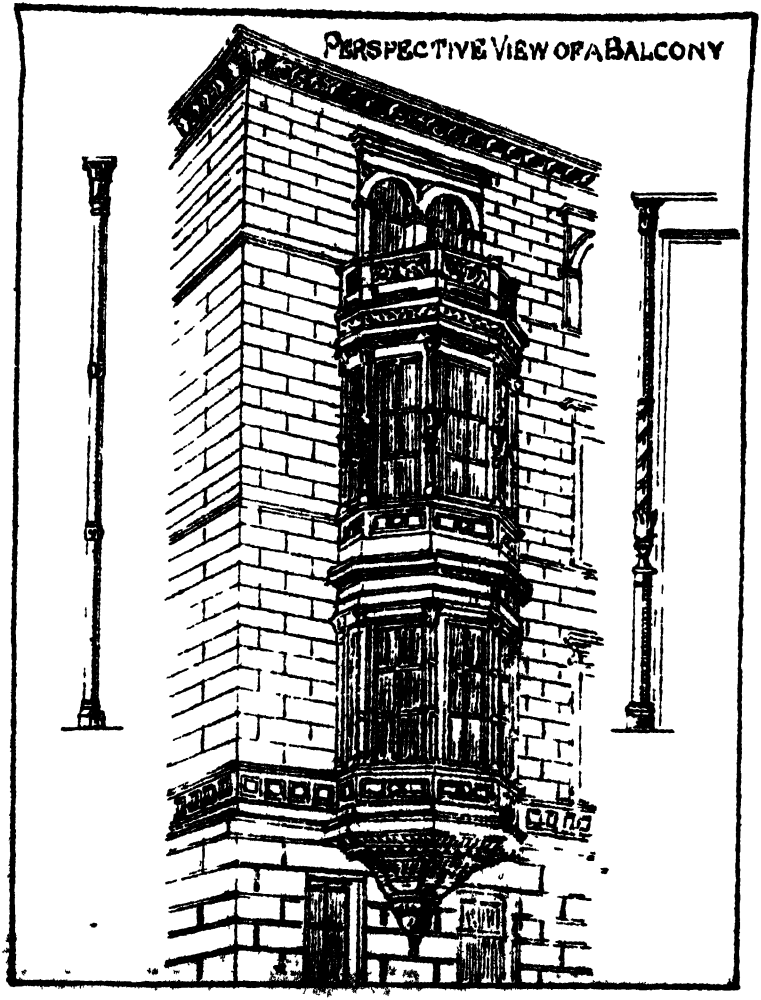

DESIGN FOR A DOOR



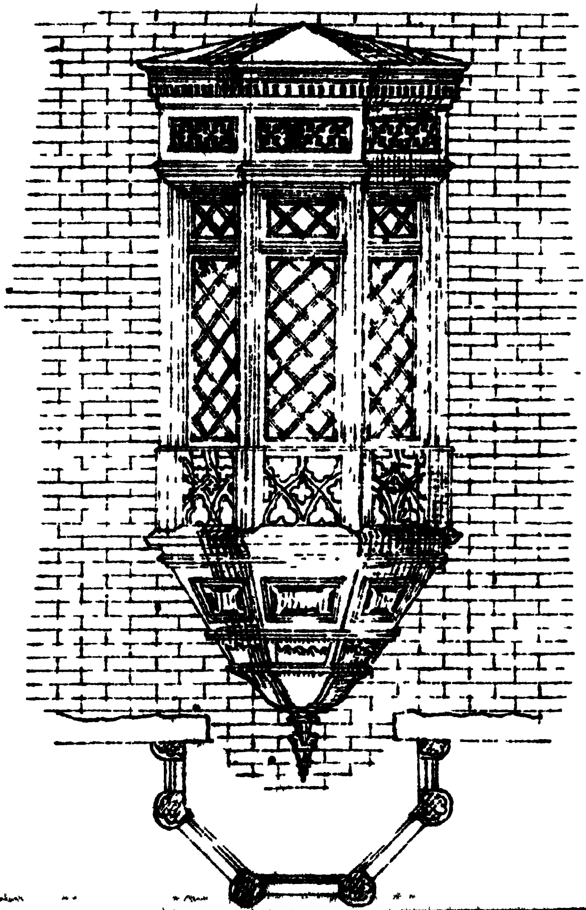
A COMPLETE ARCH OF ORIENTAL STYLE.

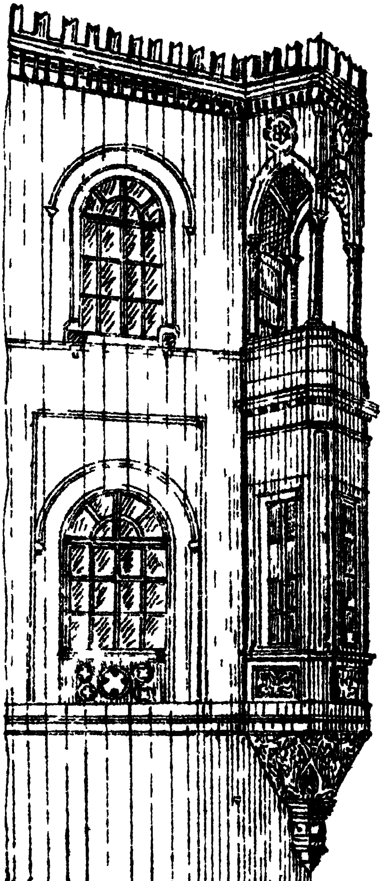
PERSPECTIVE VIEW OF A WINDOW



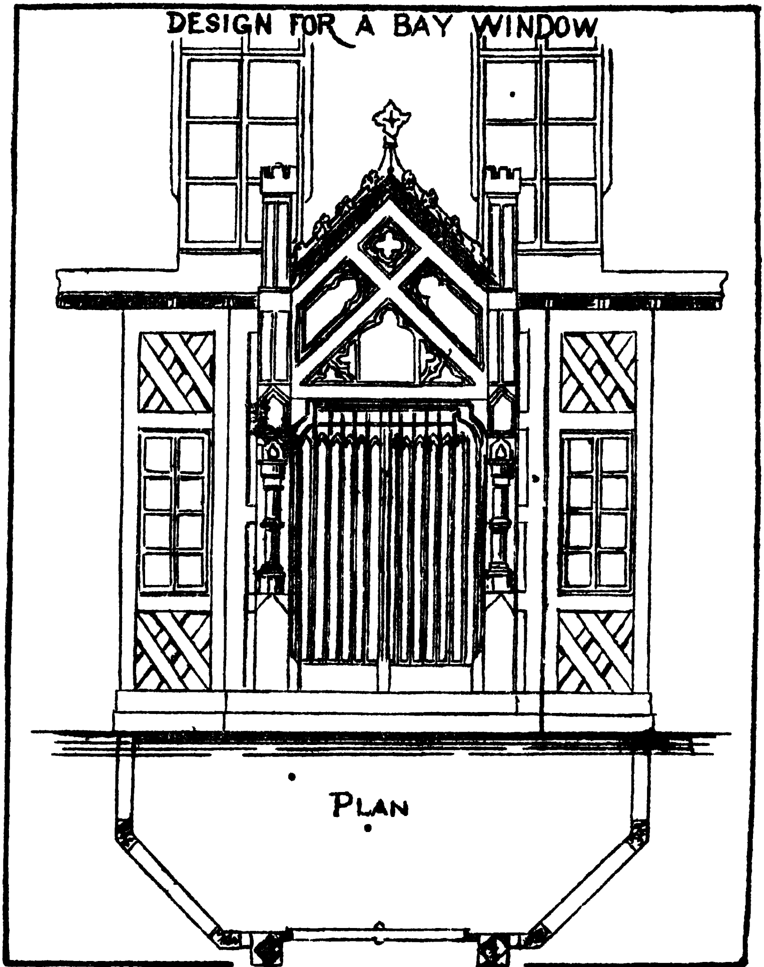

PERSPECTIVE VIEW OF A BALCONY

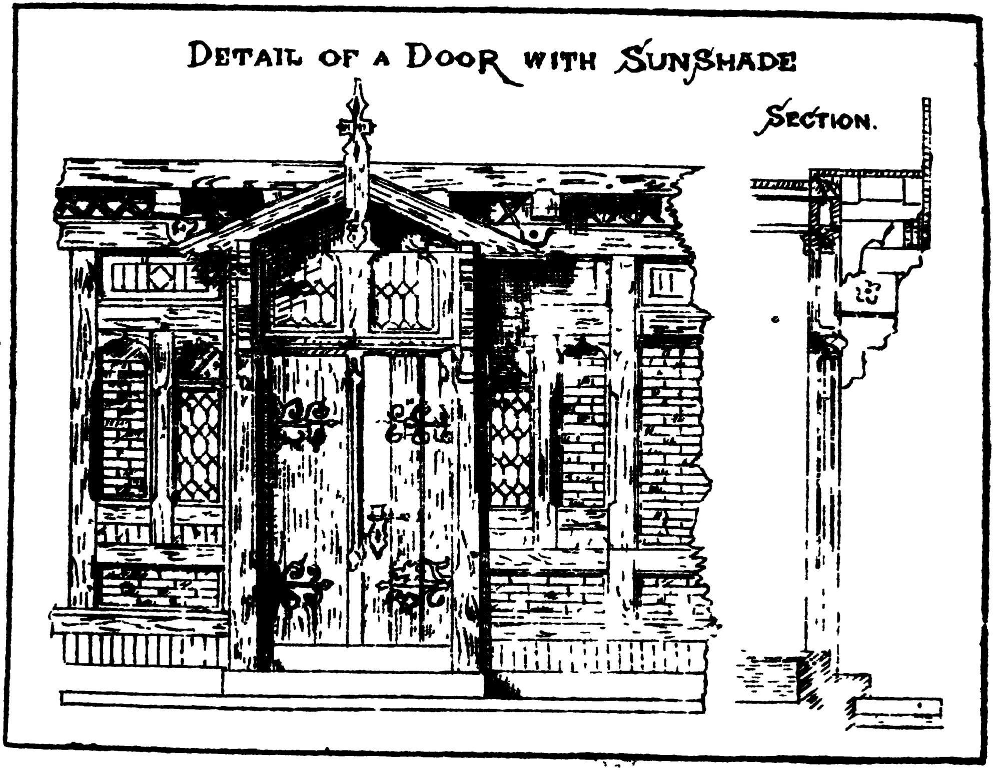
DESIGN FOR A BALCONY

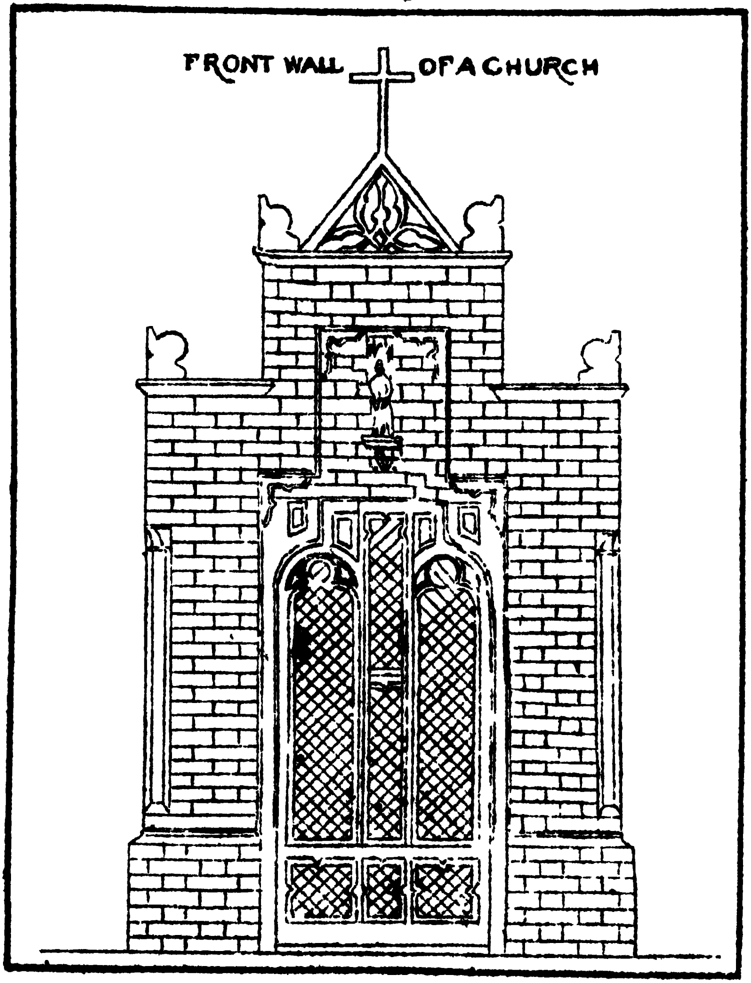


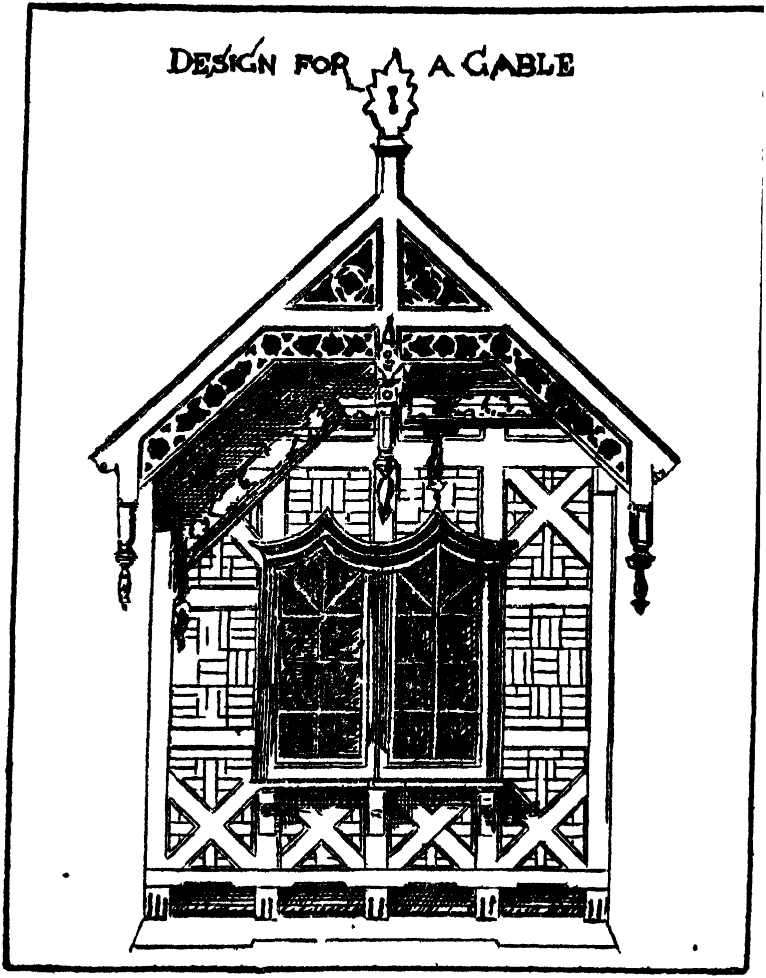


PERSPECTIVE VIEW OF A BALCONY

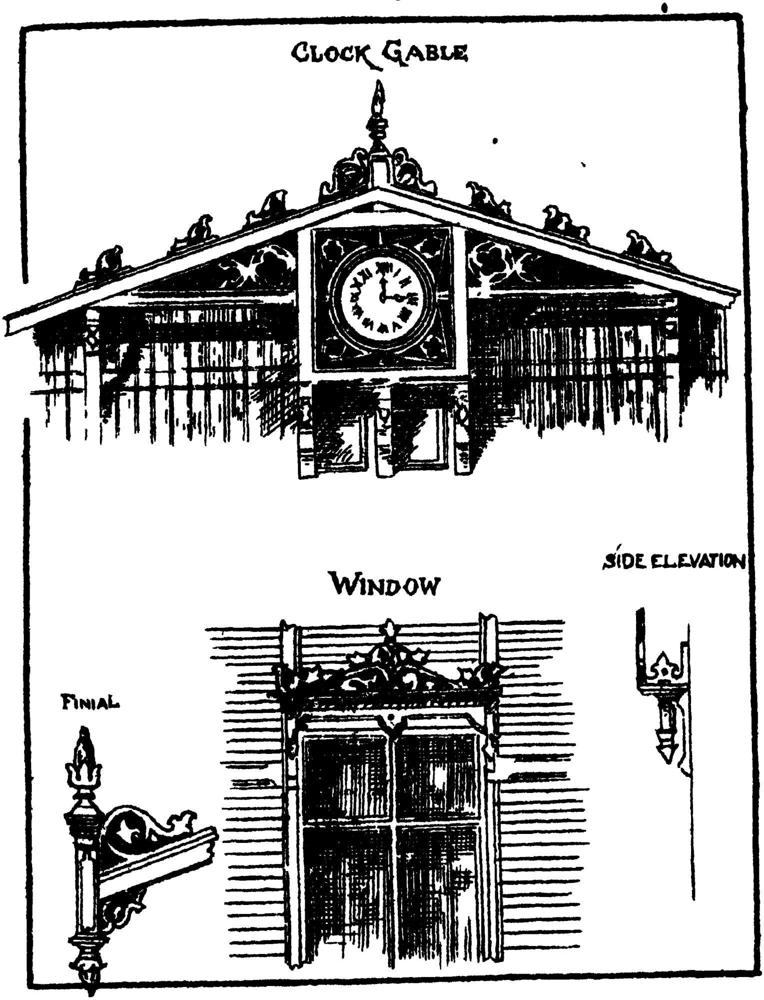

DESIGN FOR A BAY WINDOW
PLAN

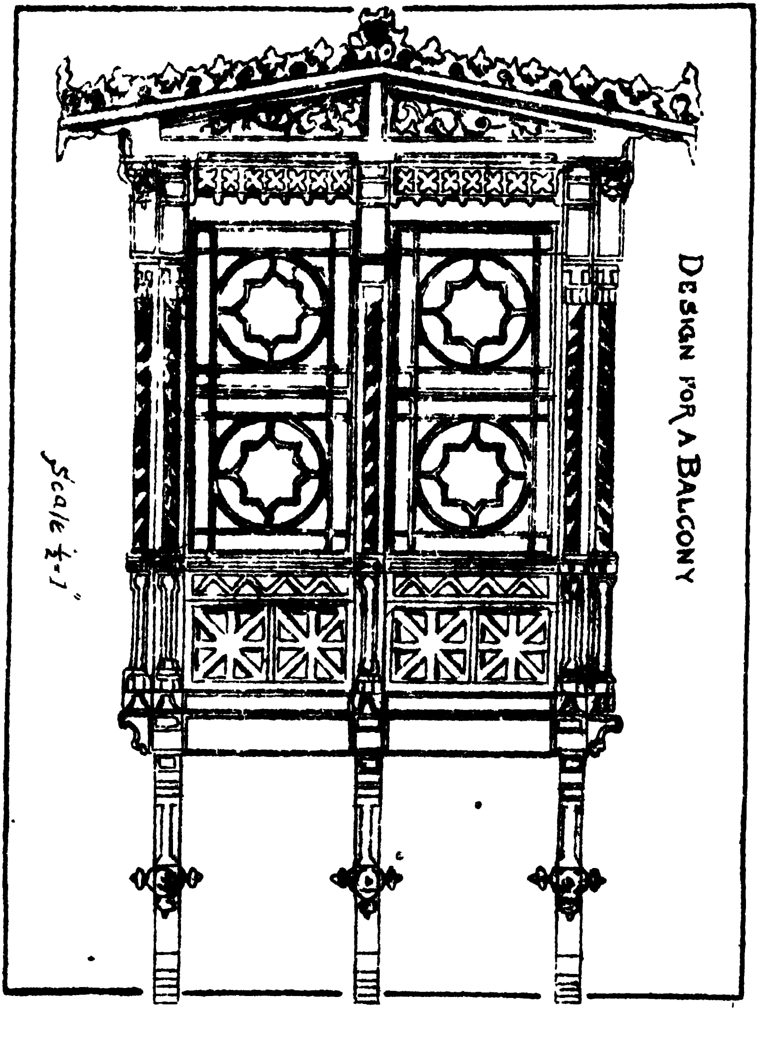

Detail of a Door with Sunshade
Section.


FRONT WALL OF A CHURCH

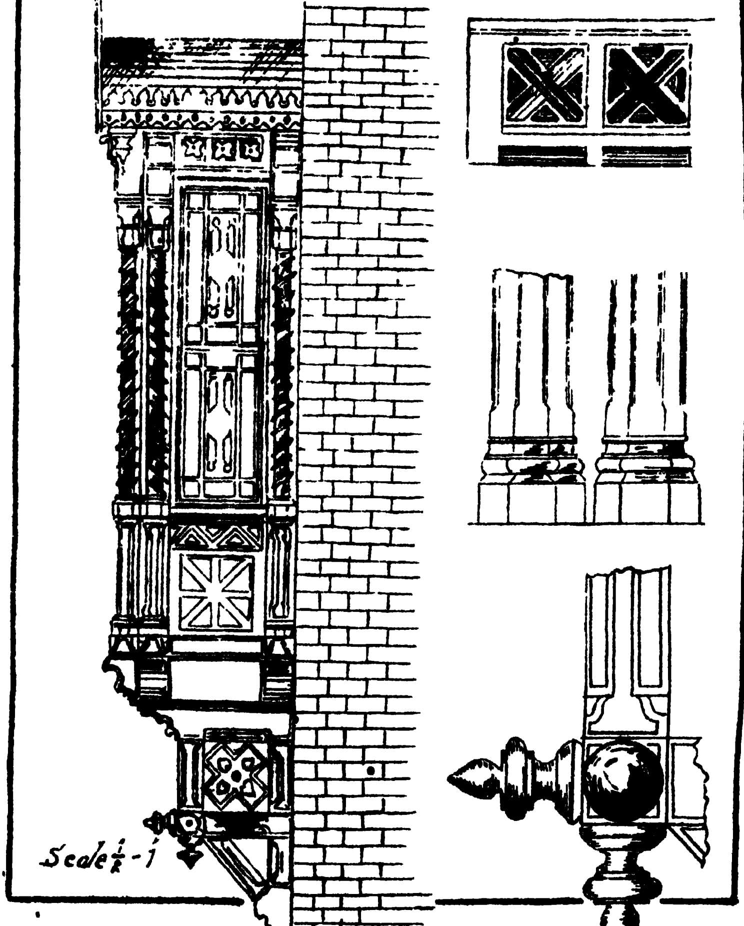


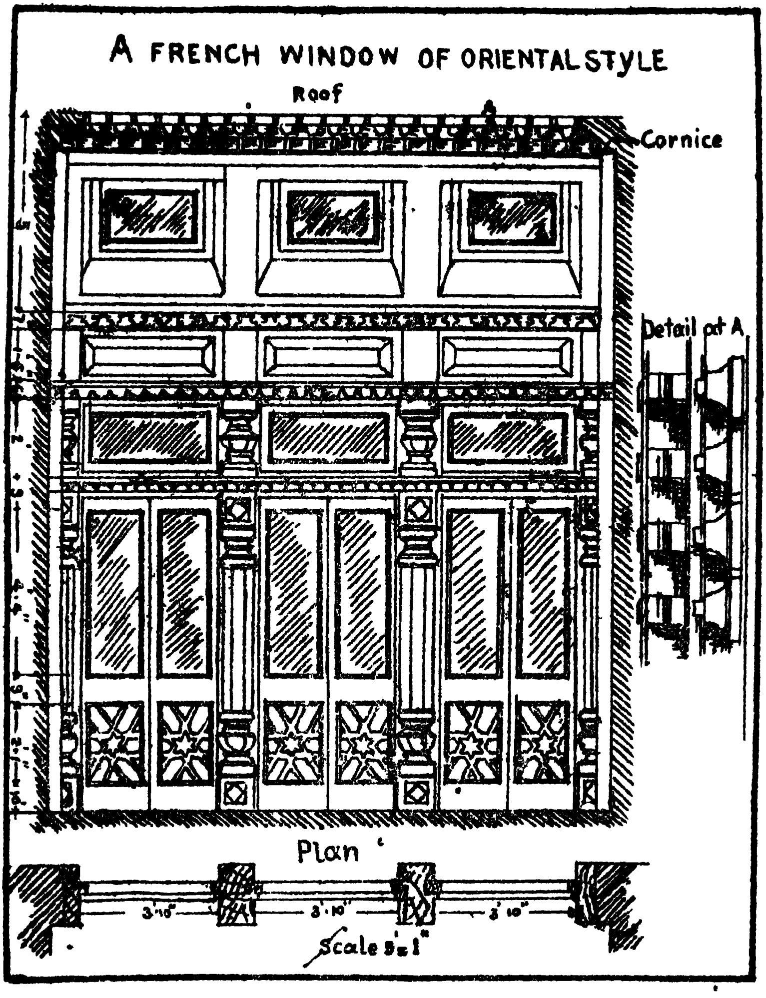
DESIGN FOR A GABLE


CLOCK GABLE
WINDOW
SIDE ELEVATION
FINIAL

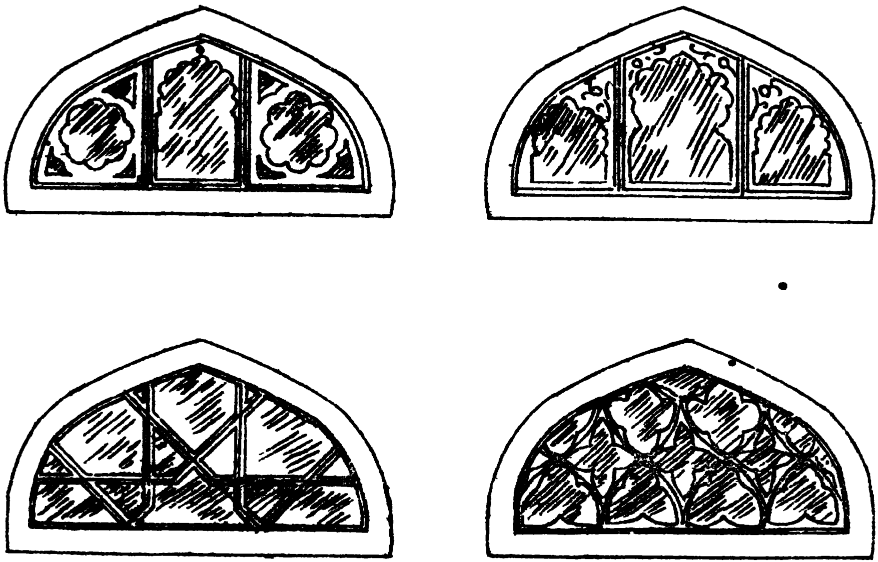

DESIGN FOR A BALCONY
Scale ½-1"

Side Elevation and Details

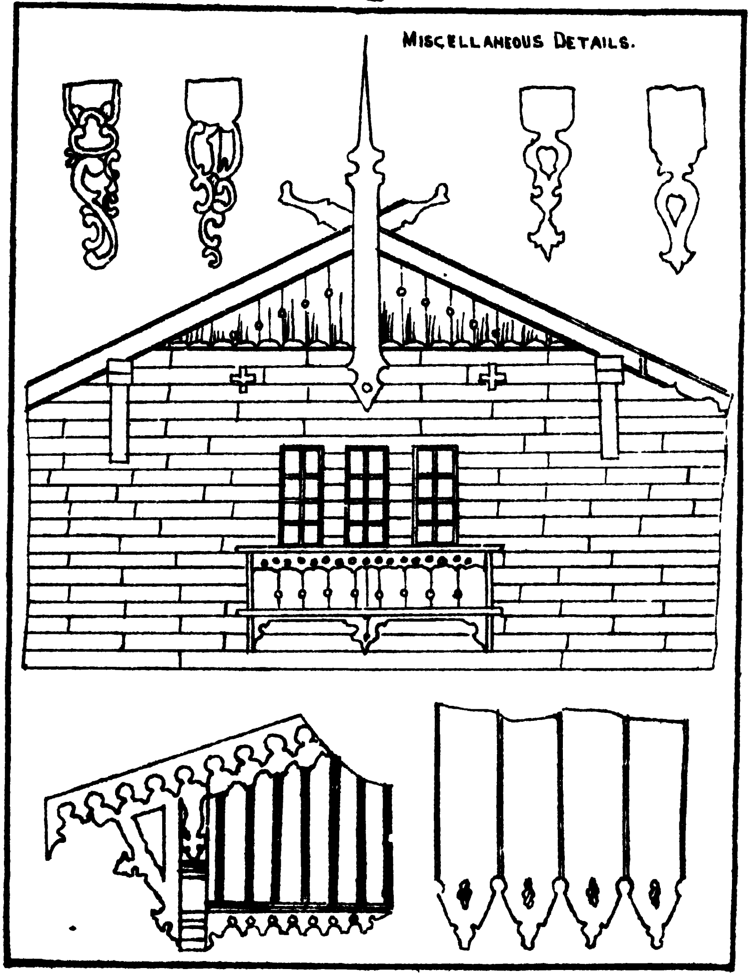


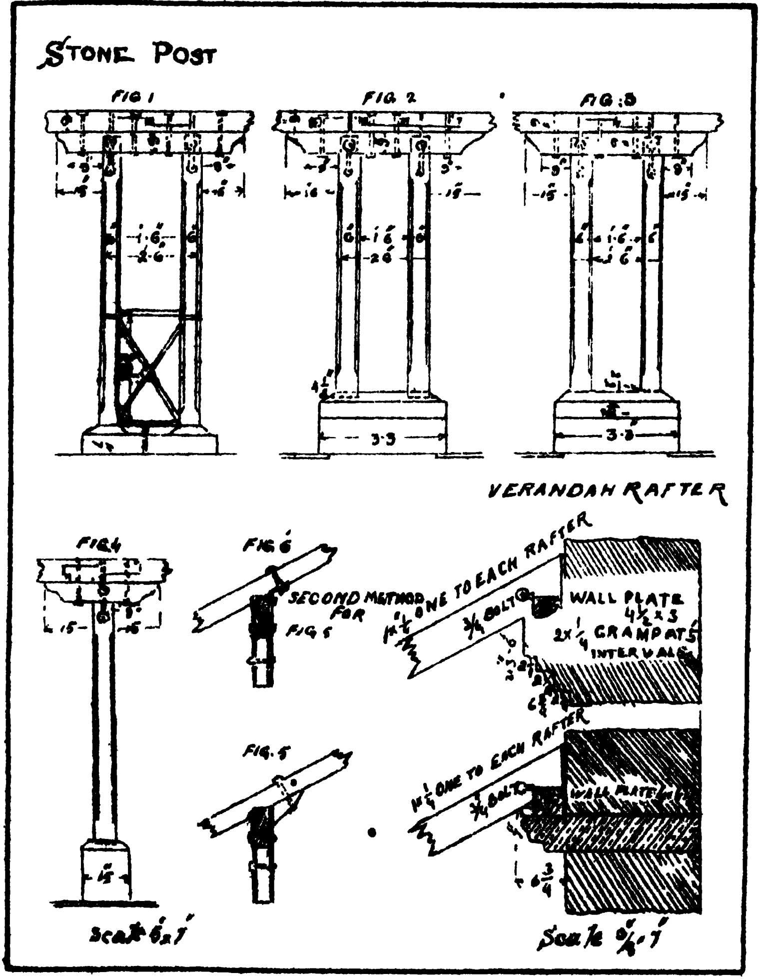

A FRENCH WINDOW OF ORIENTAL STYLE
Roof
Cornice
Detail at A
Plan
3'10"
3'10"
3'10"
Scale 5'=1"

FAN LIGHTS OVER DOORS.

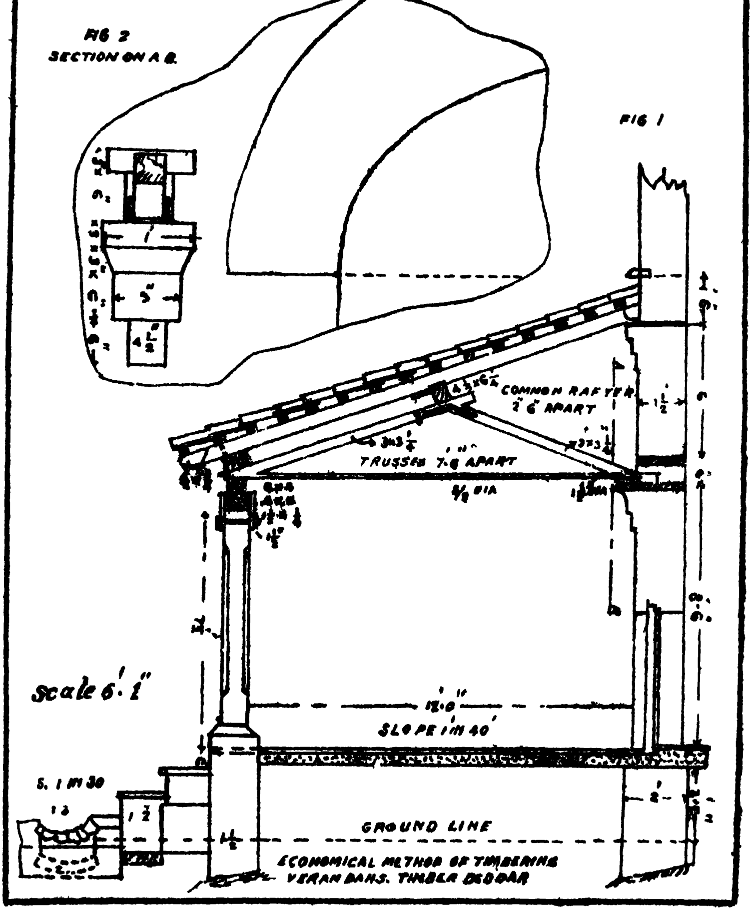


SCALE ½" = 1'

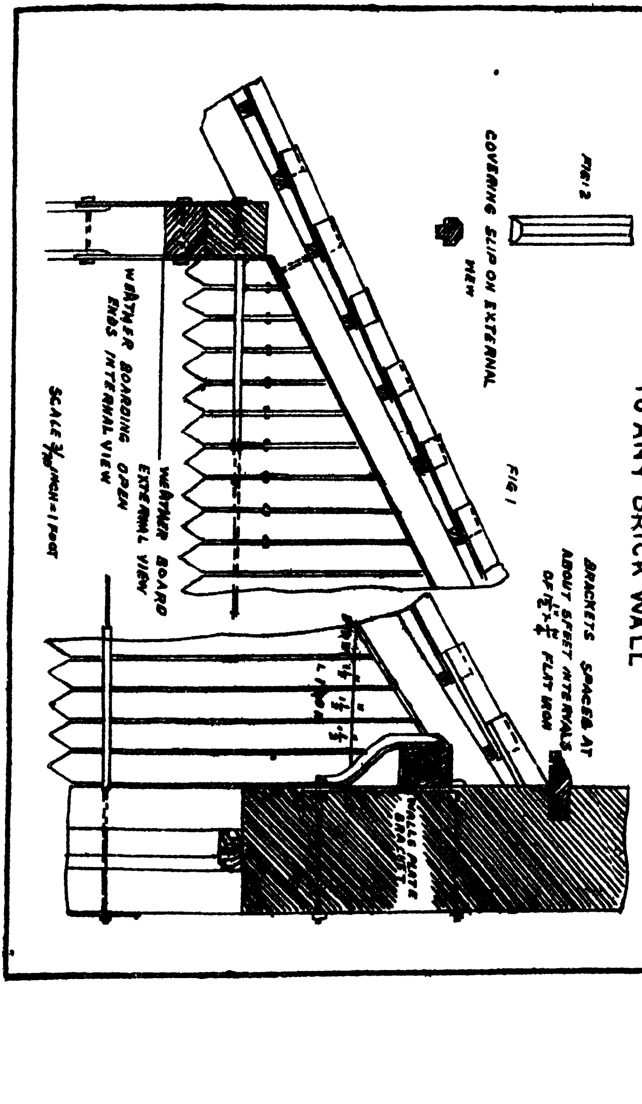

MISCELLANEOUS DETAILS.


STONE POST
FIG 1
FIG. 2
FIG 3
3·3
VERANDAH RAFTER
FIG 4
FIG 6
SECOND METHOD FOR FIG 5
ONE TO EACH RAFTER
3/4 BOLT
WALL PLATE 4½ x 3
2 x ¼ CRAMP AT 5' INTERVALS
FIG. 5
ONE TO EACH RAFTER
3/4 BOLT
WALL PLATE

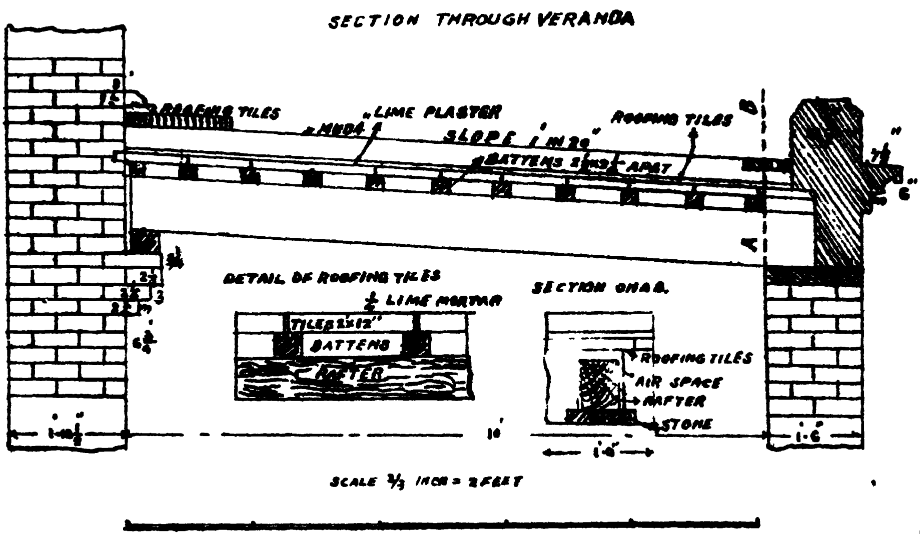
DETAIL OF VERANDAH

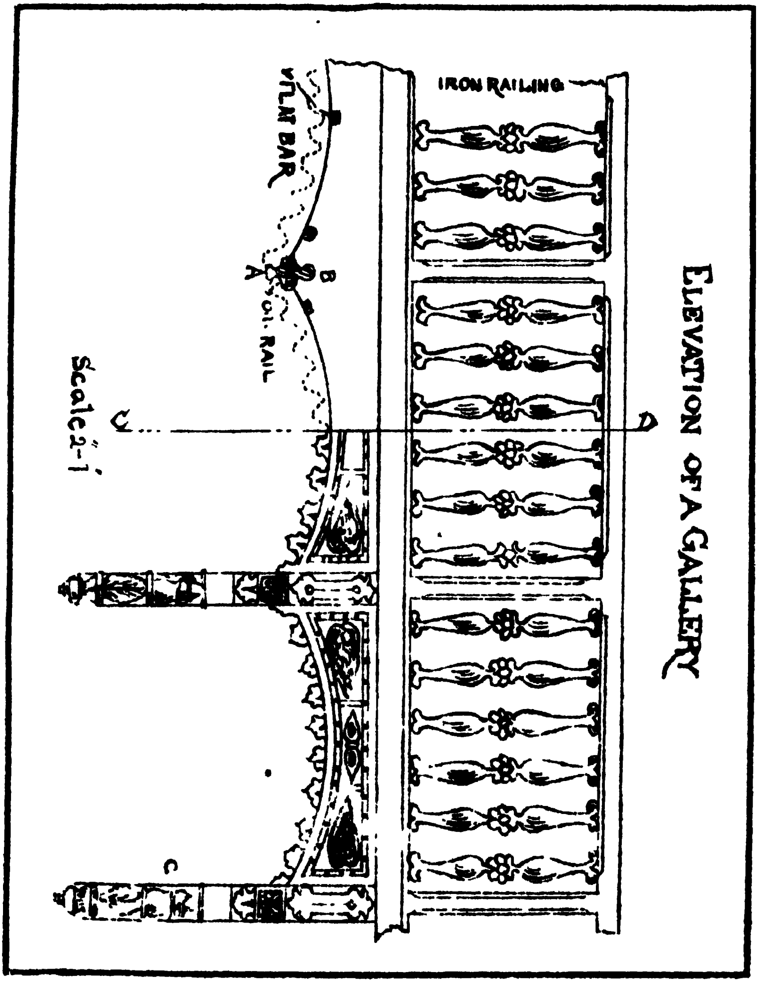


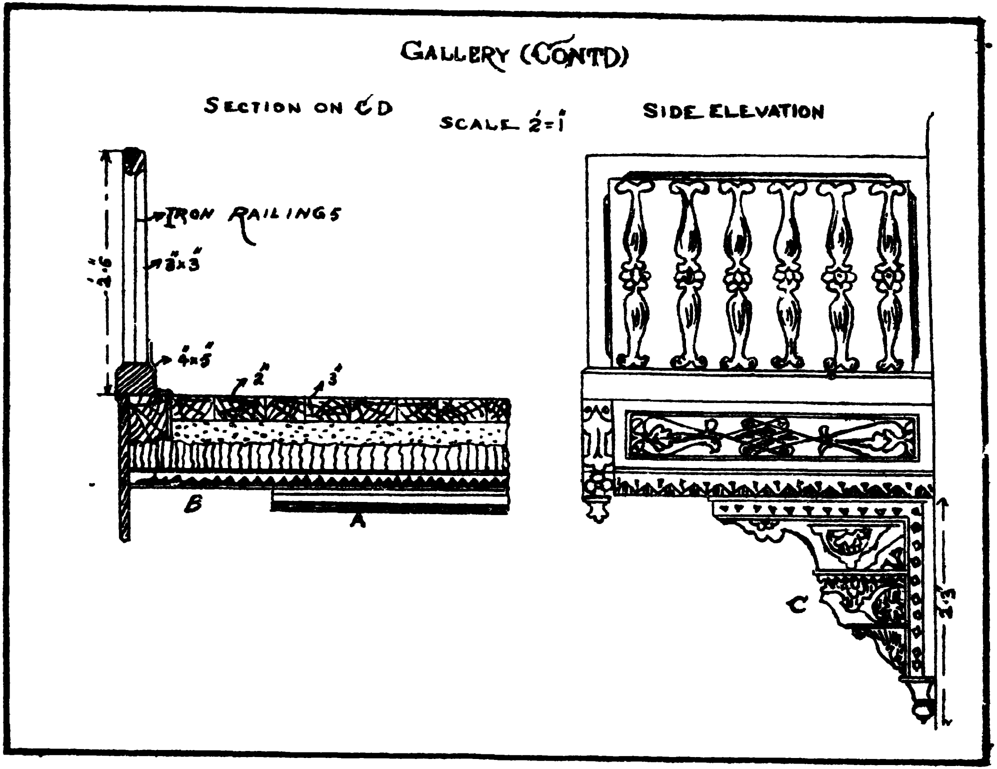
EASY METHOD OF ADDING VERANDAH TO ANY BRICK WALL

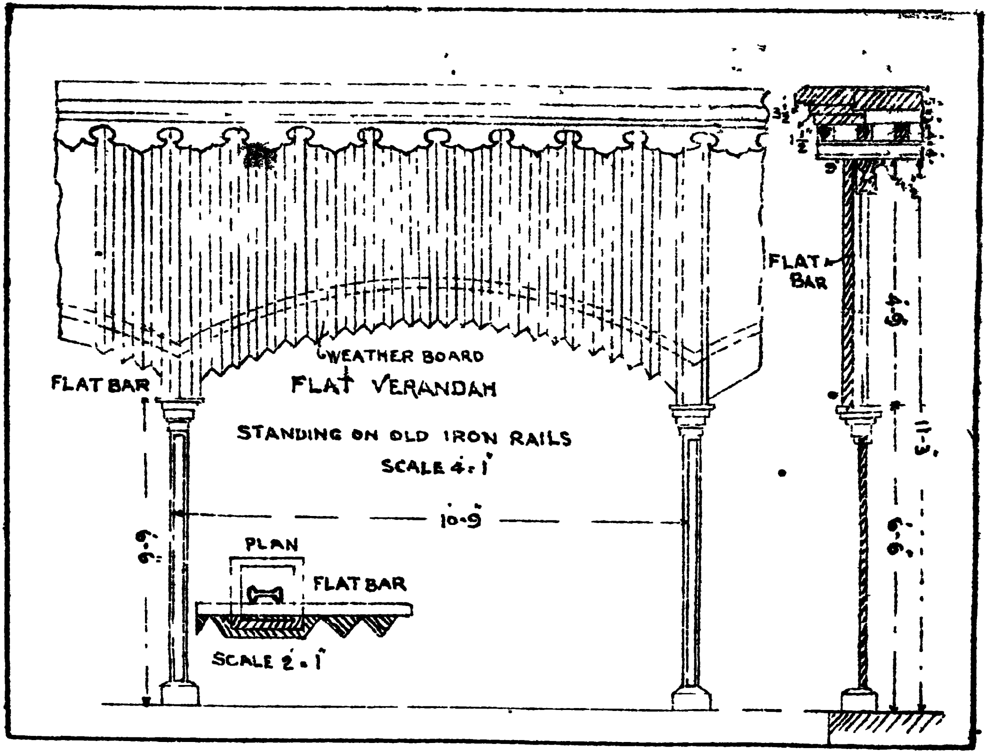


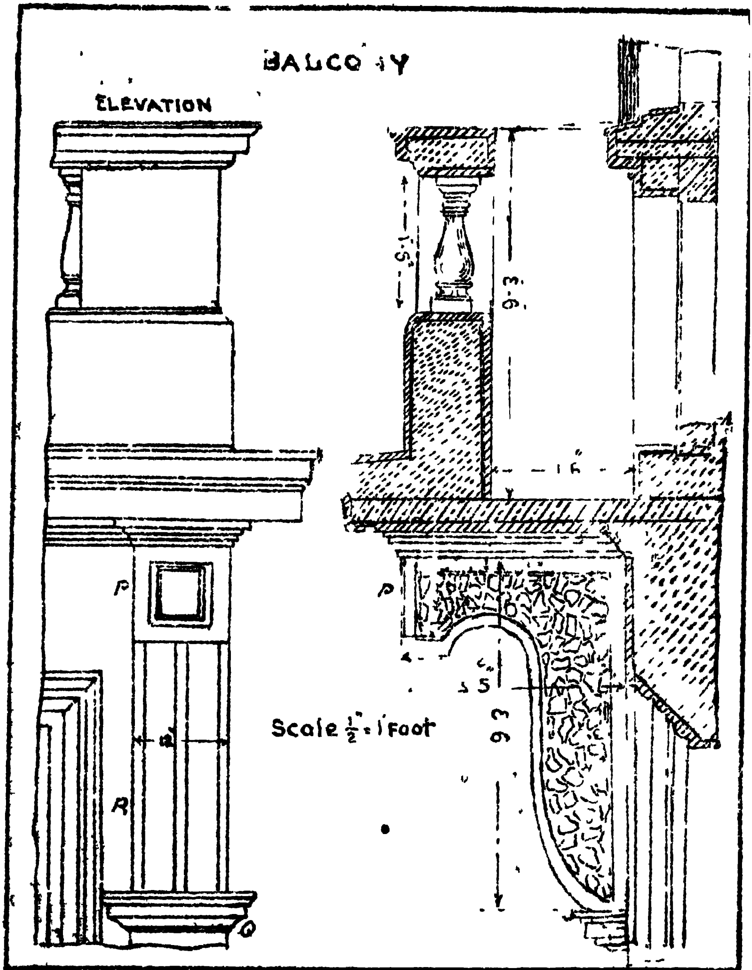
MUD VERANDAH ROOFING

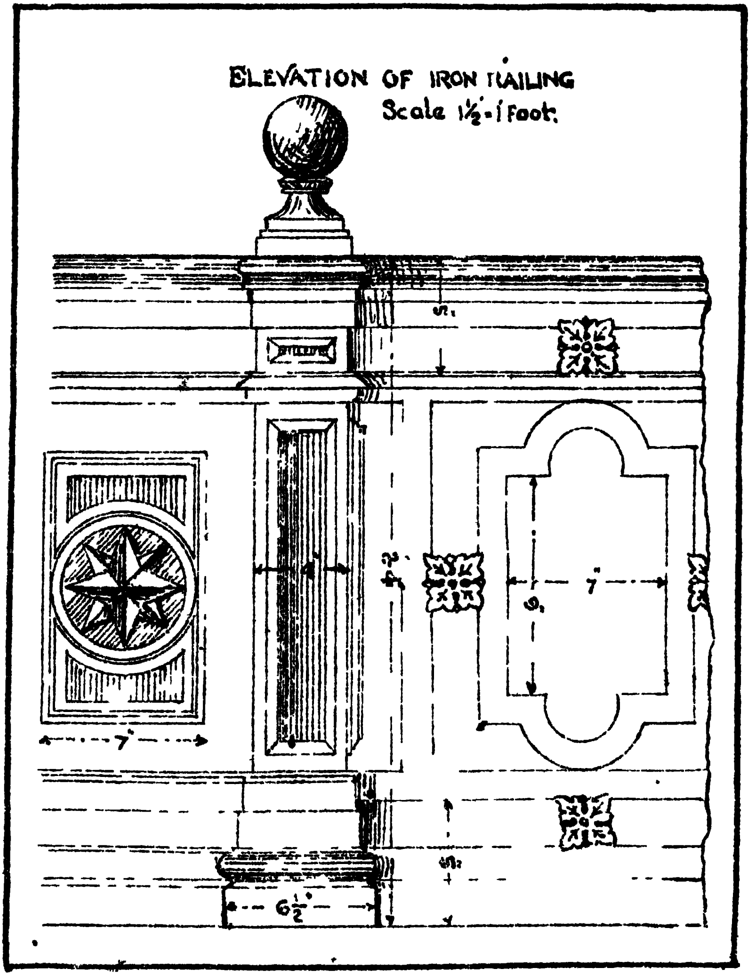


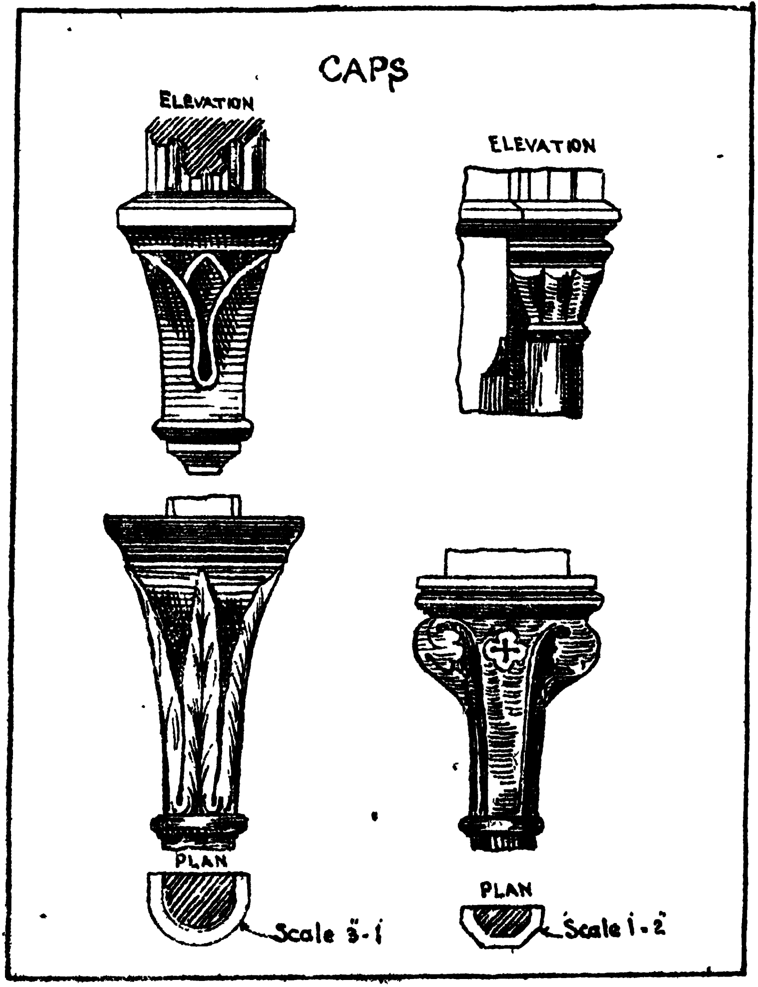

ELEVATION OF A GALLERY
IRON RAILING
FLAT BAR
A
B
COL. RAIL
C
D
Scale 2"-1'

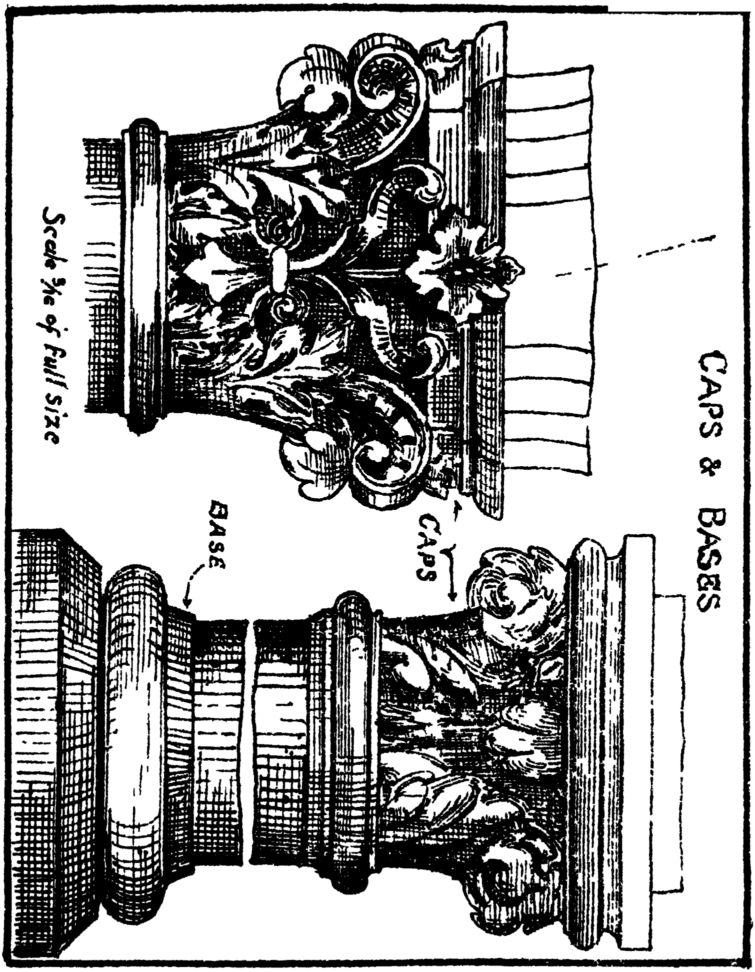

GALLERY (CONTD)
SECTION ON CD
SCALE 2'=1"
SIDE ELEVATION
IRON RAILINGS
2'6"
3/4"x3/4"
4"x5"
2"
3"
B
A
C
2'3"

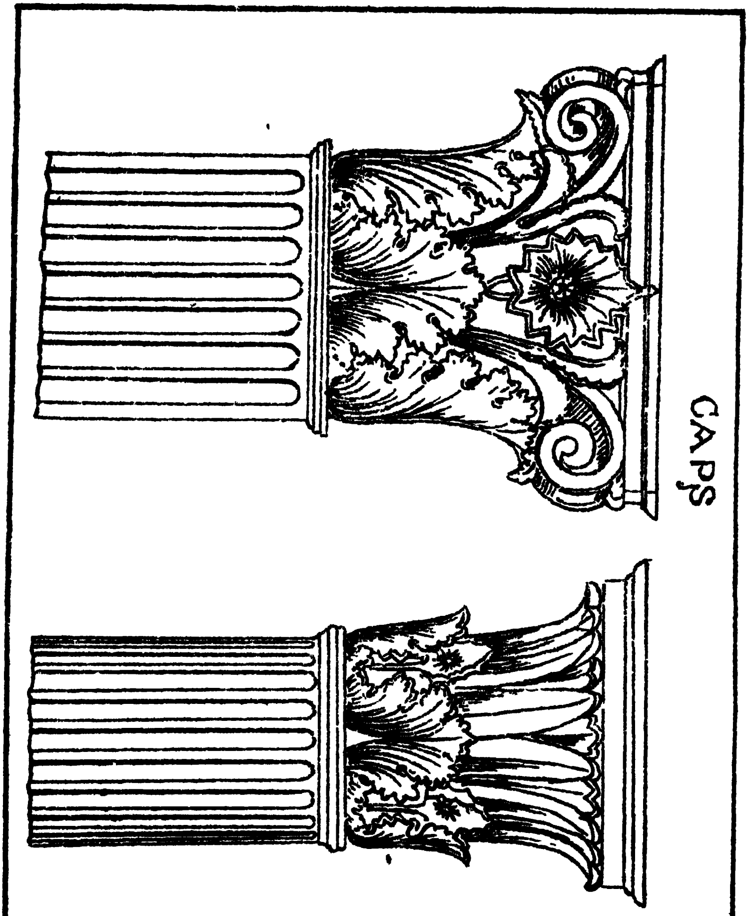

WEATHER BOARD
FLAT VERANDAH
STANDING ON OLD IRON RAILS
SCALE 4 : 1"
FLAT BAR
10-9"
9'-9"
PLAN
FLAT BAR
SCALE 2 : 1"
FLAT BAR
4'-9"
6'-6"
11'-3"

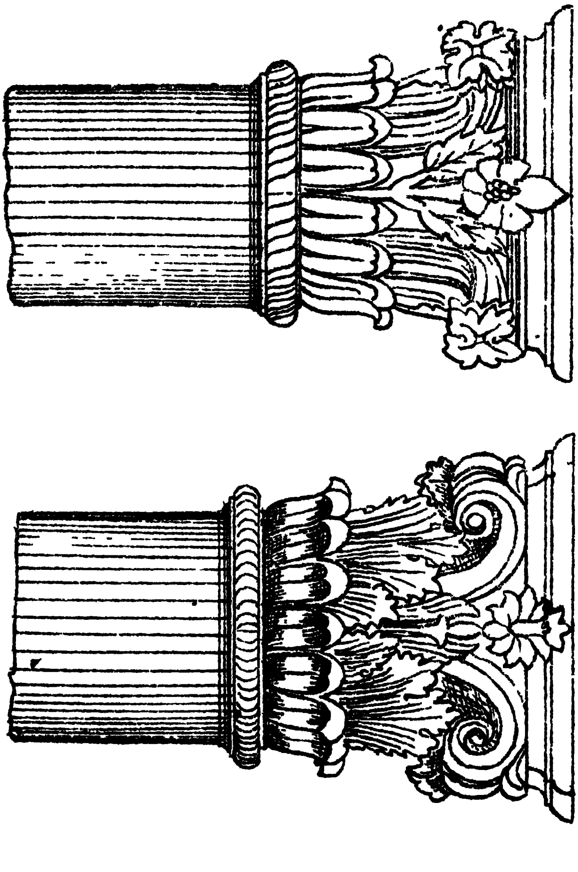

BALCONY
ELEVATION
1'5"
9'3"
1'6"
P
P
R
Q
12"
5
9'3"
Scale ½" = 1 Foot


ELEVATION OF IRON RAILING
Scale 1½"=1 Foot.
7"
7"
6½"

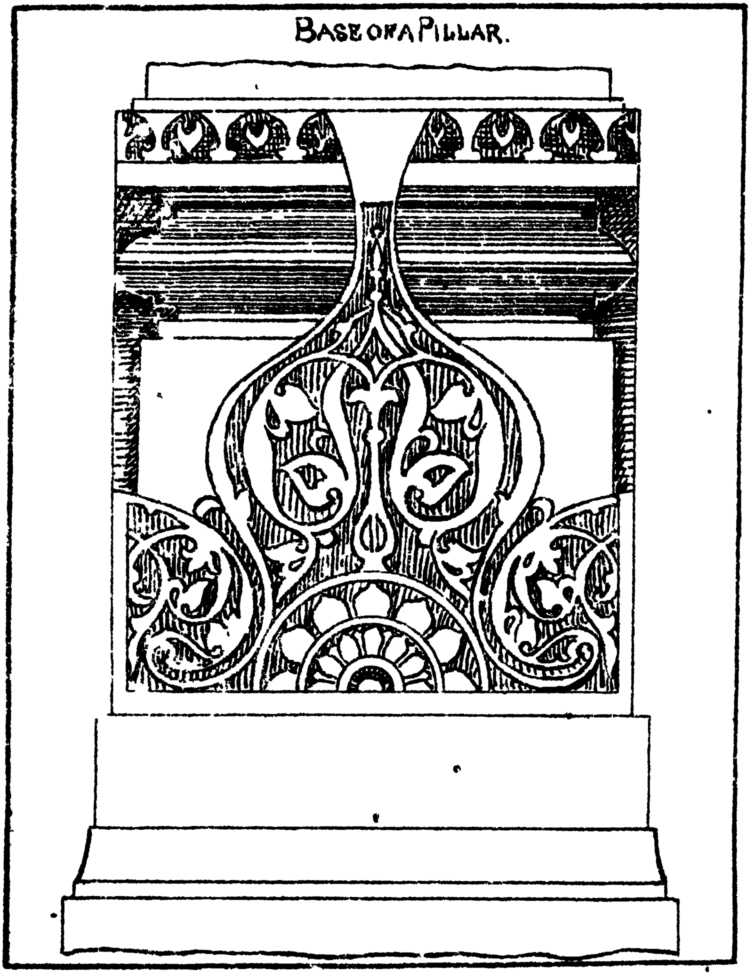

CAPS
ELEVATION
ELEVATION
PLAN
Scale 3"-1
PLAN
Scale 1-2"


CAPS & BASES
CAPS
BASE
Scale 3/16 of full size

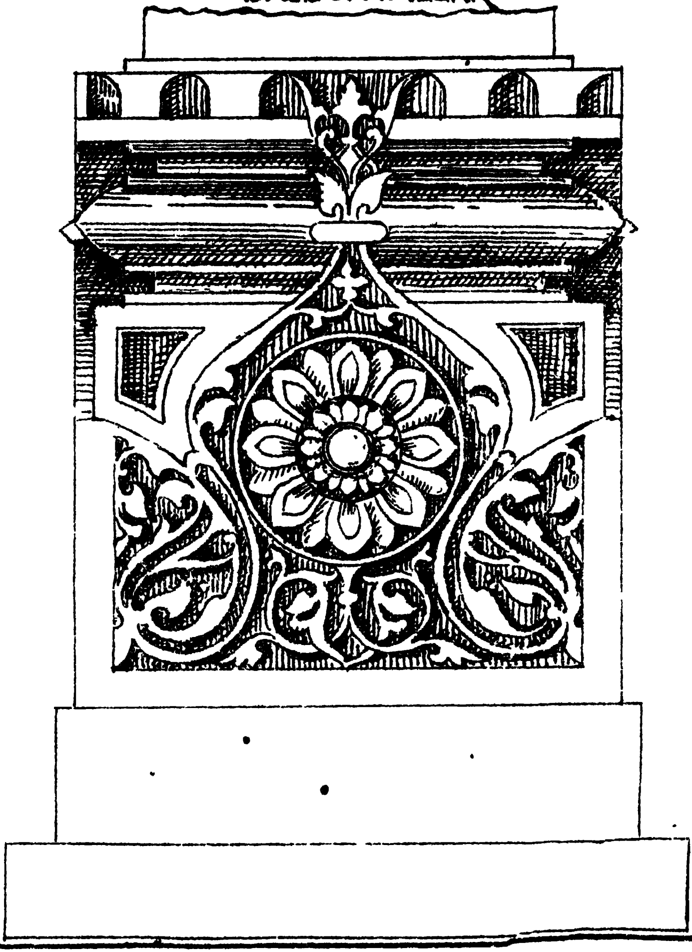

CAPS

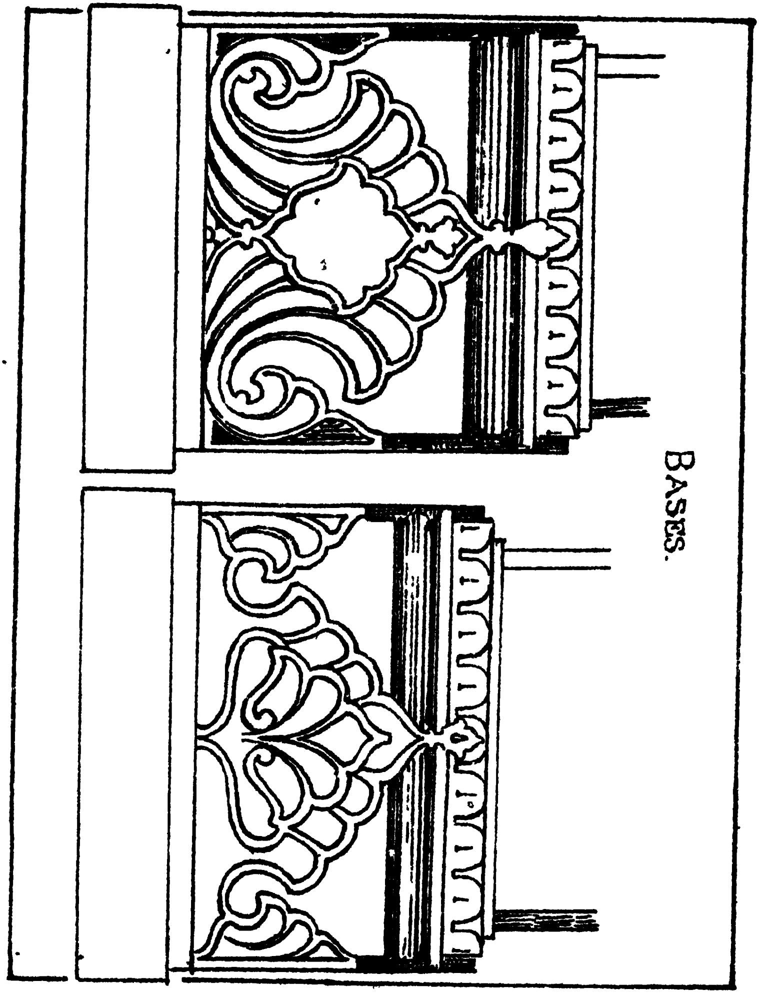


CAPS


BASE OF A PILLAR.

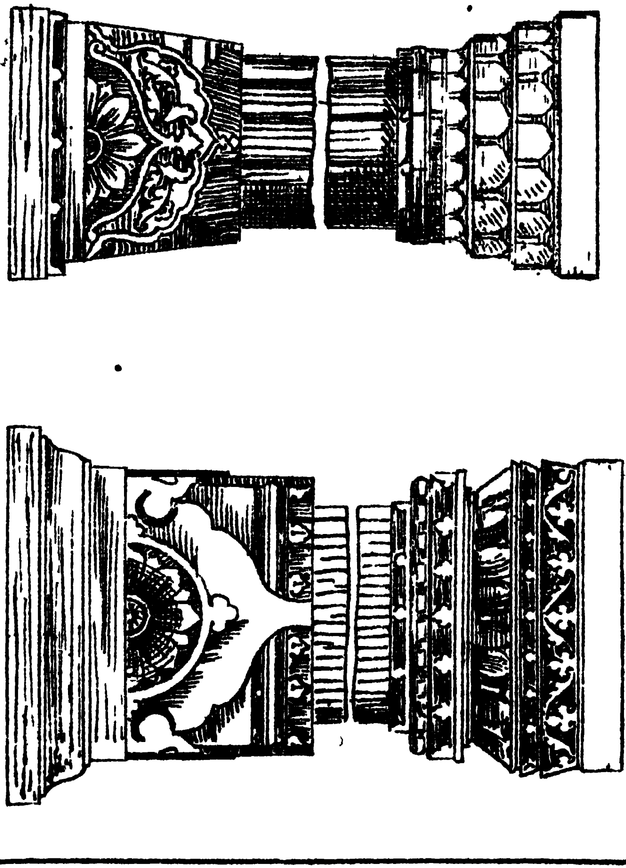
BASE OF A PILLAR





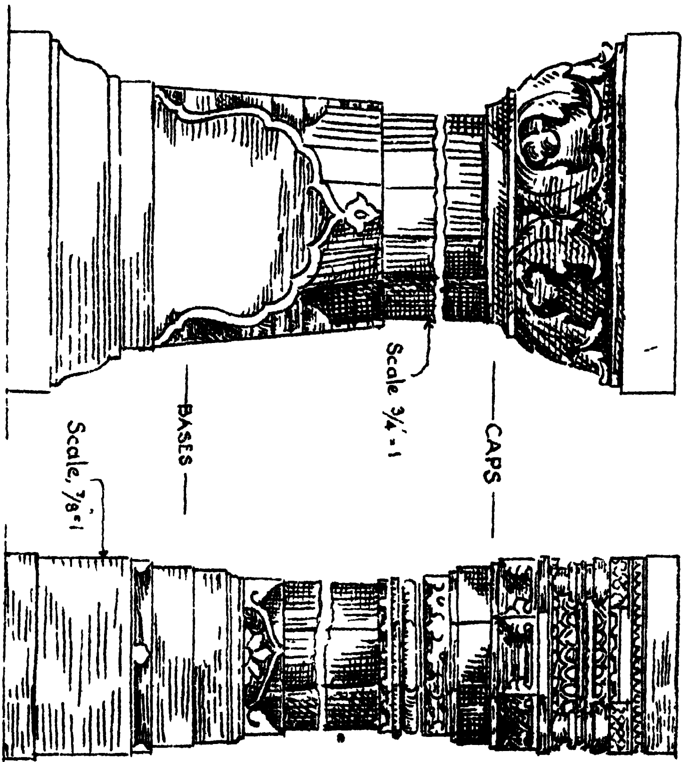
BASES.

STONE PILLARS.

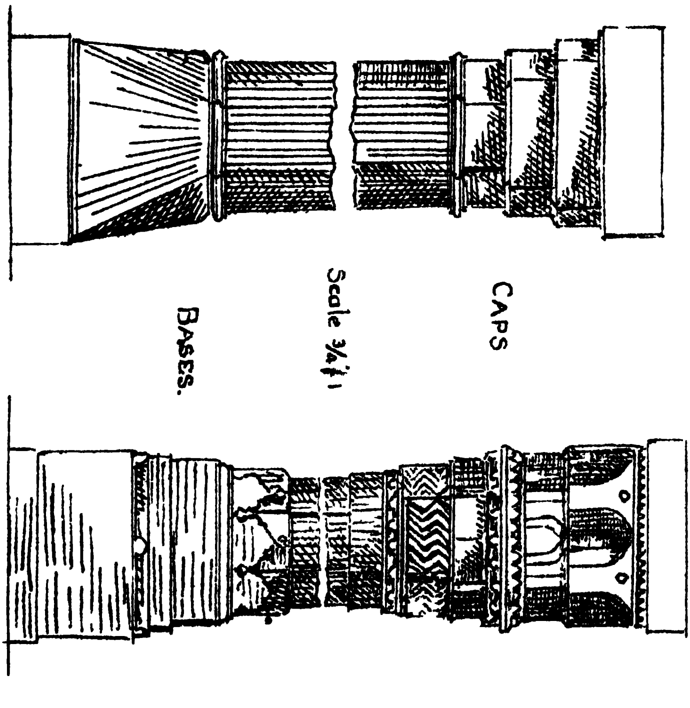


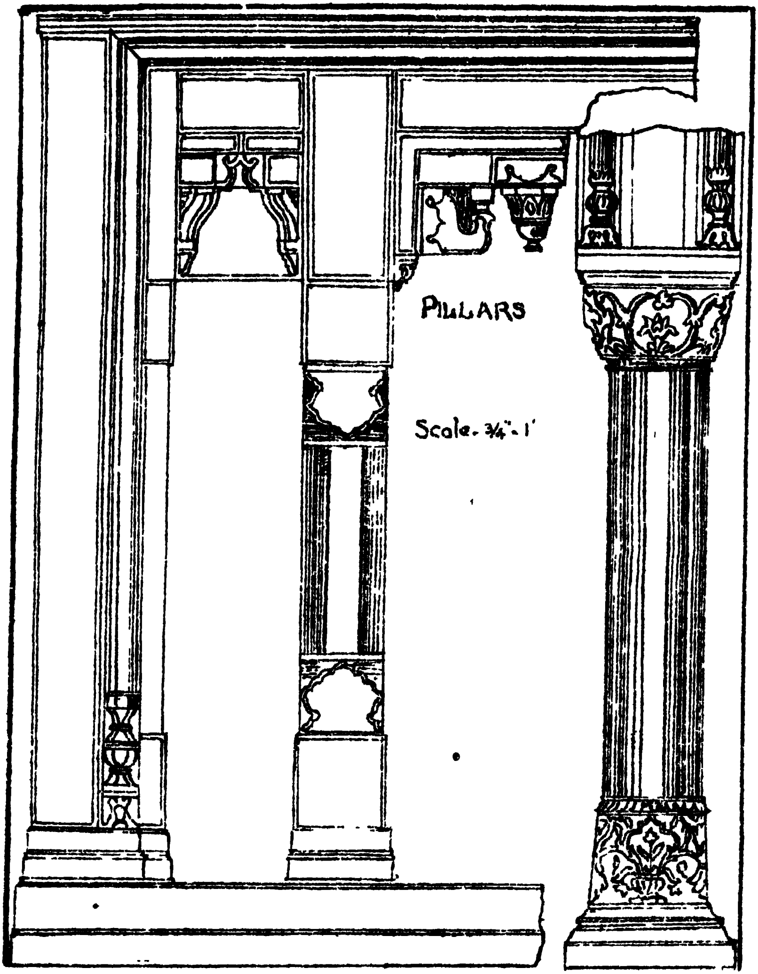
CAPS & BASES

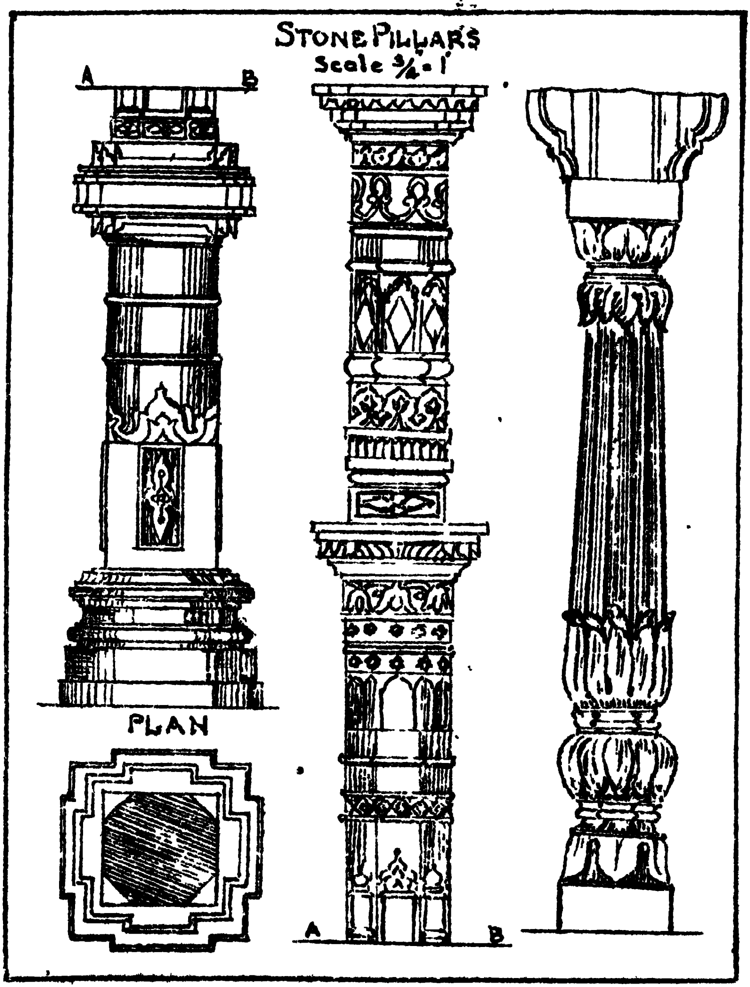
CAPS & BASES OF PILLARS.

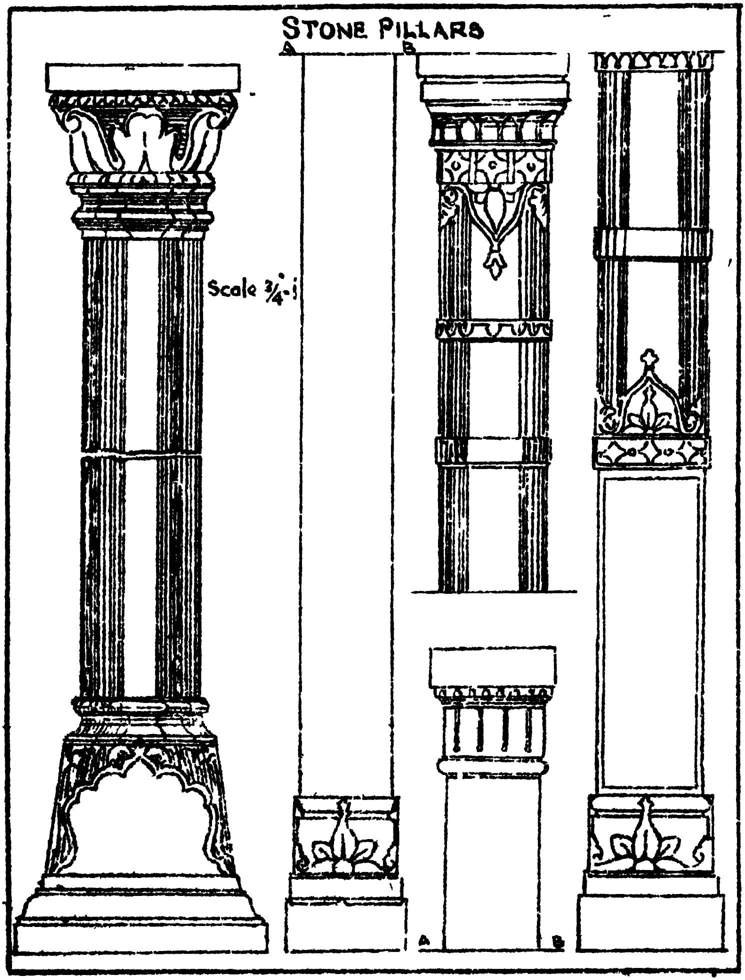


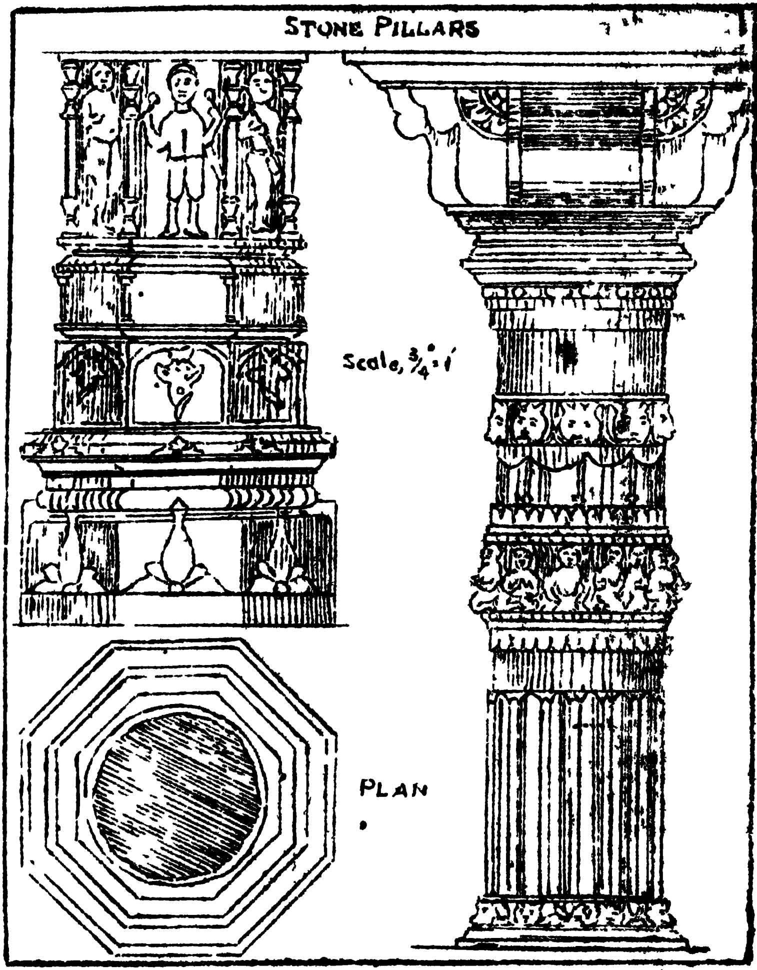
PILLARS

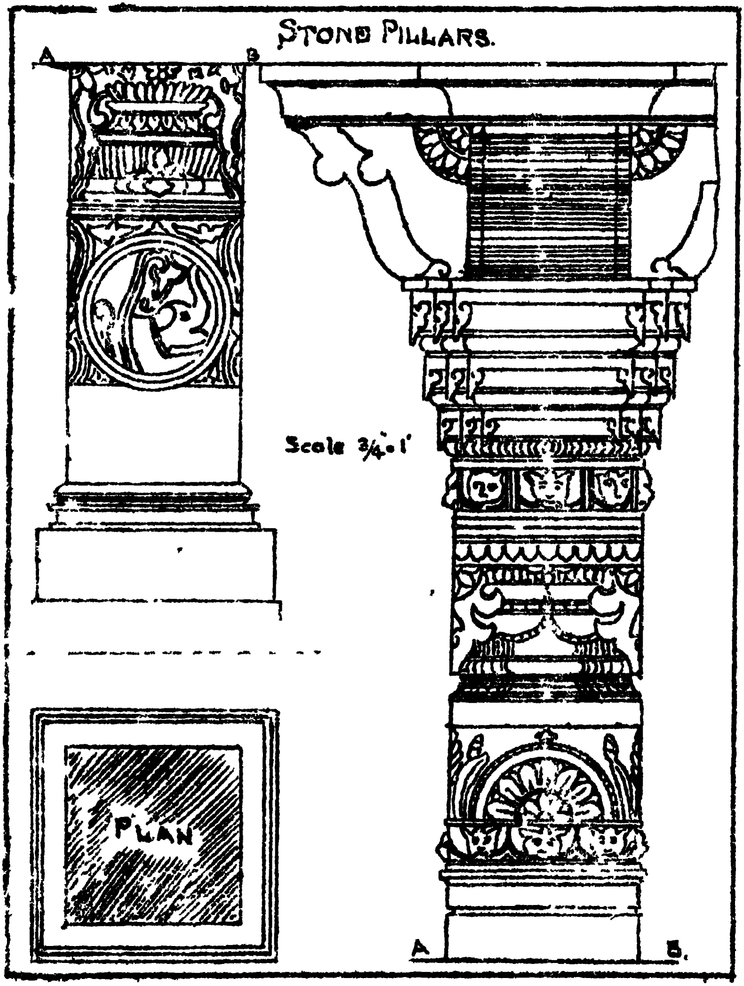


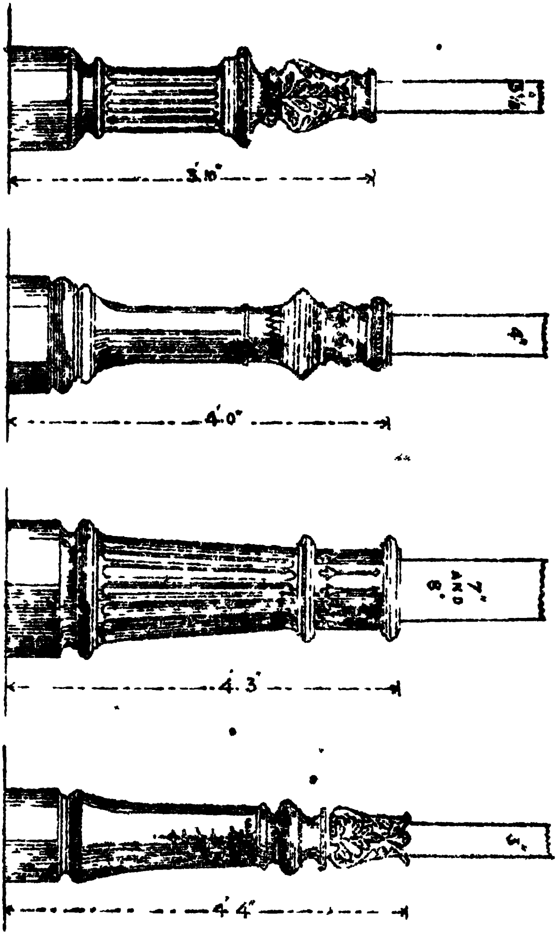

PILLARS
Scale. 3/4" - 1'


STONE PILLARS
Scale 3/4 = 1
A
B
PLAN
A
B

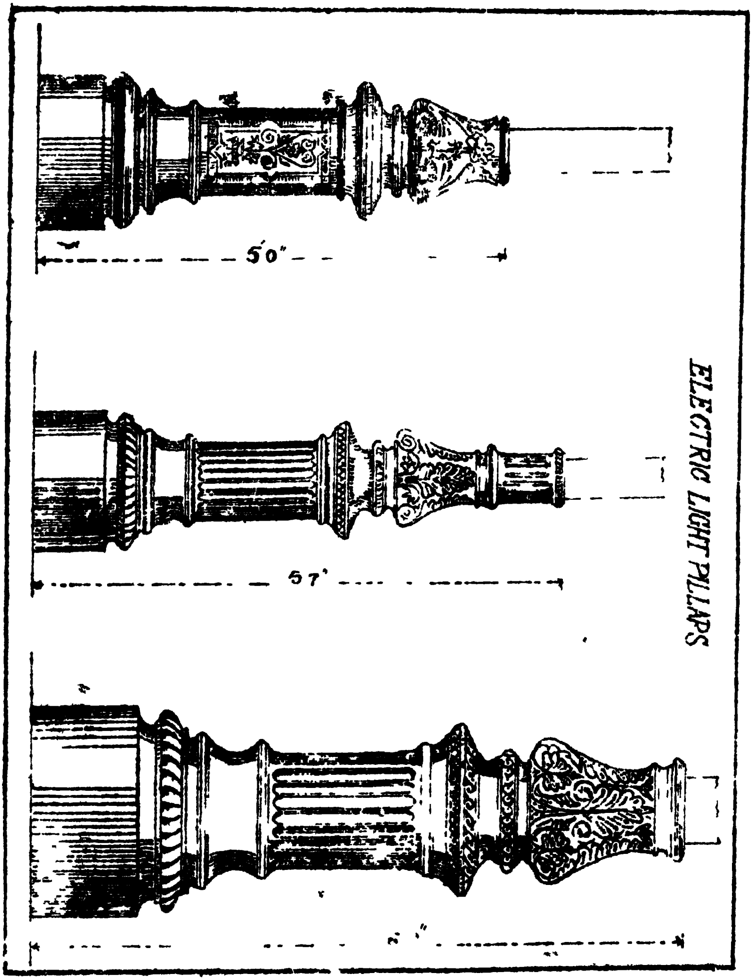

STONE PILLARS
A
B
Scale 3/4"-1'
A
B

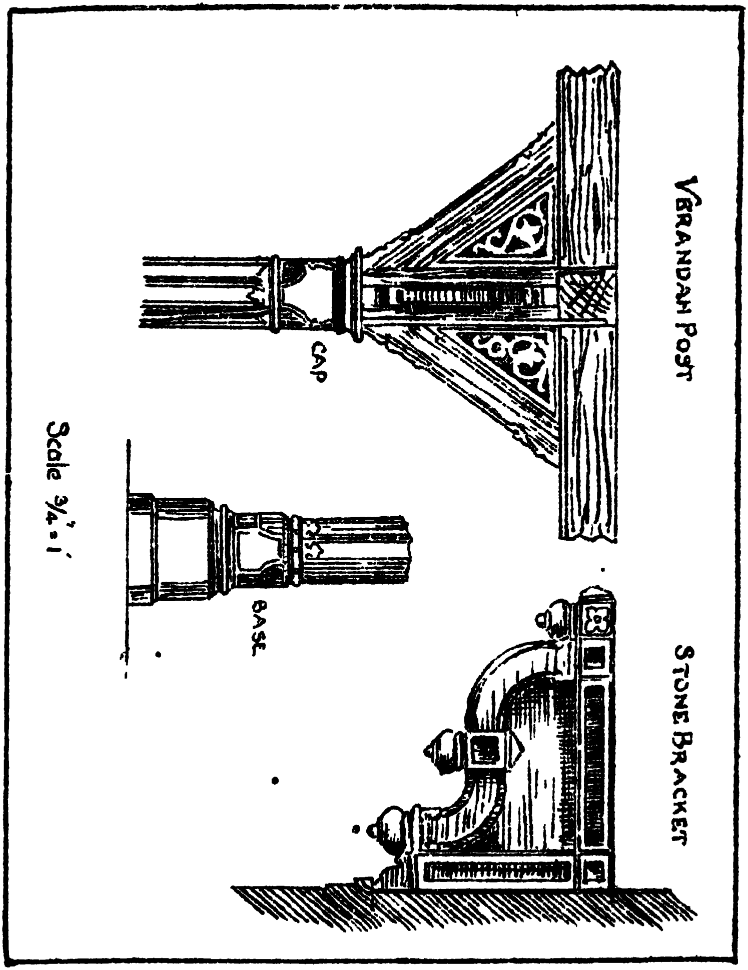

STONE PILLARS
Scale, 3/4"=1'
PLAN

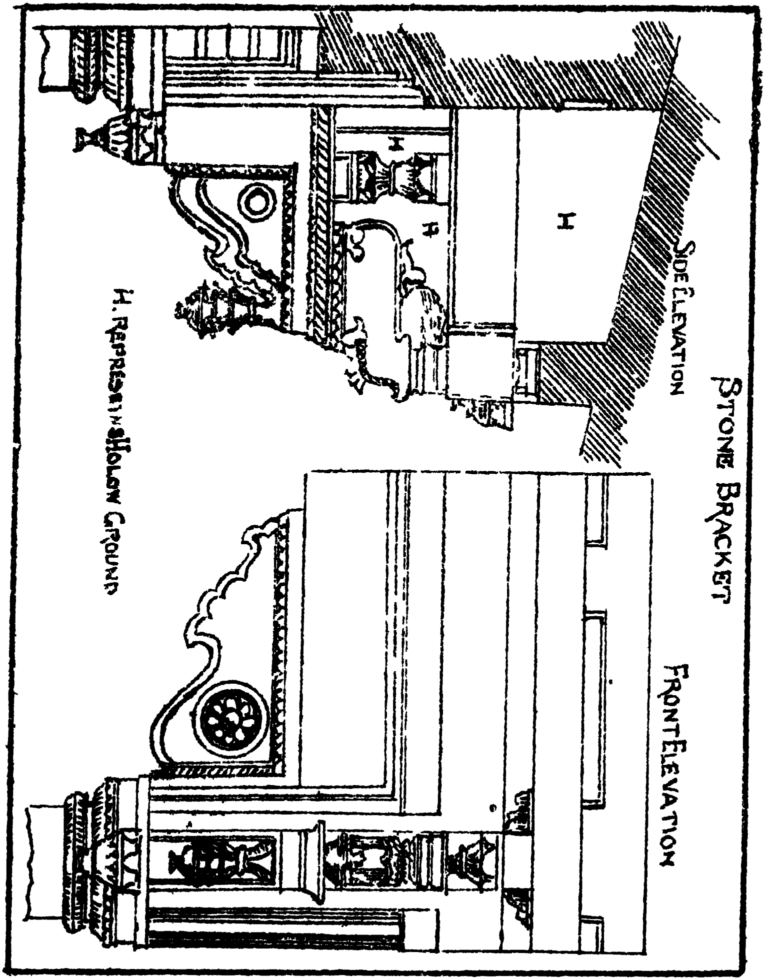

STONE PILLARS.
A
B
Scale 3/4"=1'
PLAN
A
B.

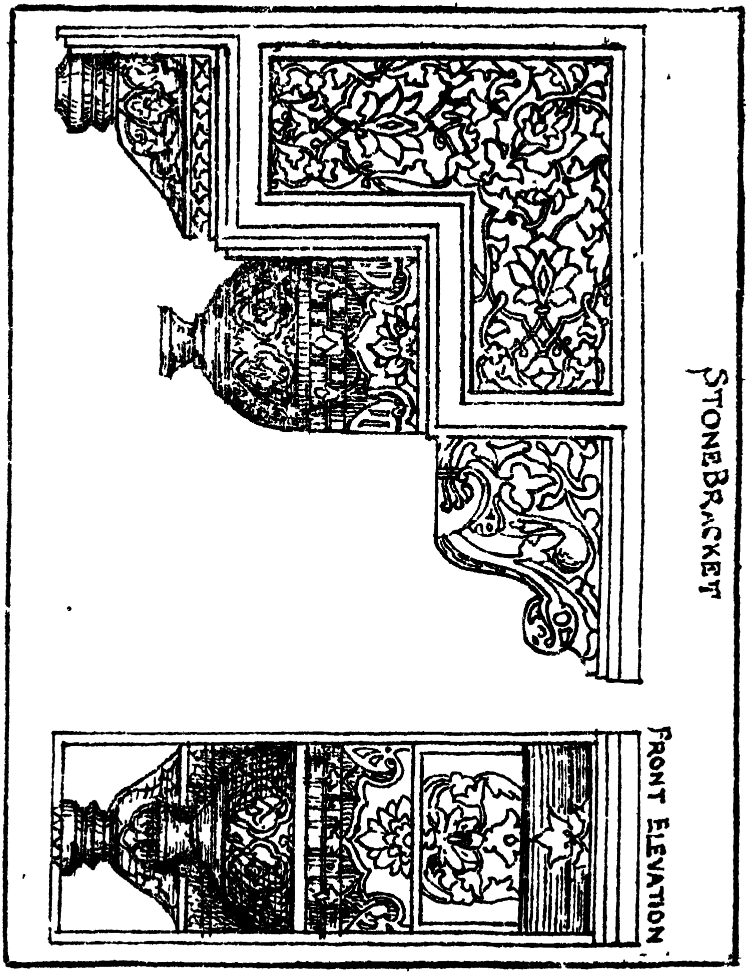


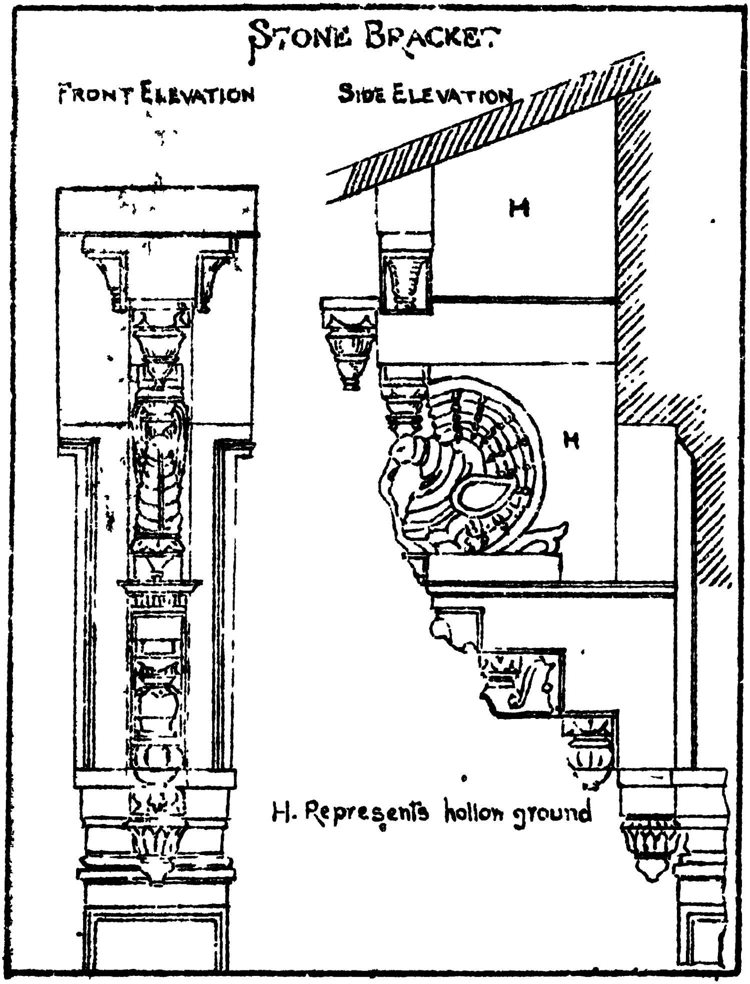
ELECTRIC LIGHT PILLARS


ELECTRIC LIGHT PILLARS
5'0"
5'7'

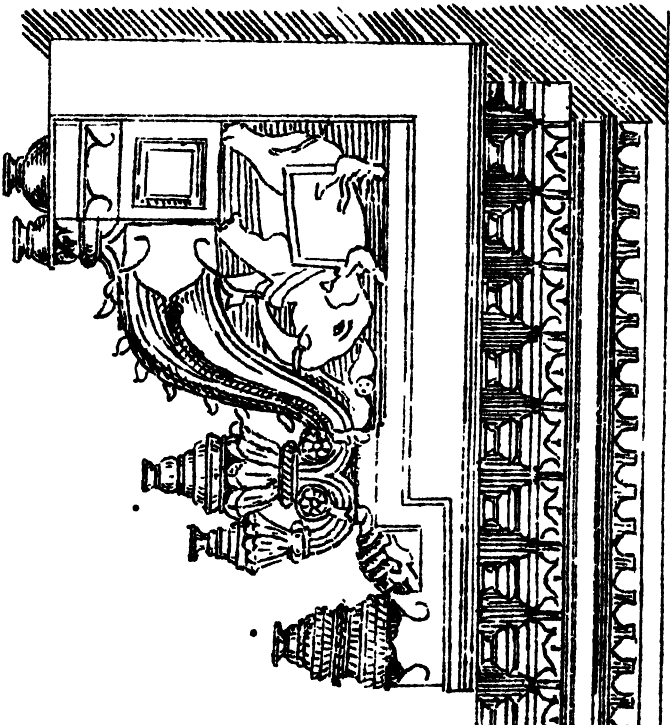

VERANDAH POST
CAP
BASE
Scale ¾" = 1'
STONE BRACKET

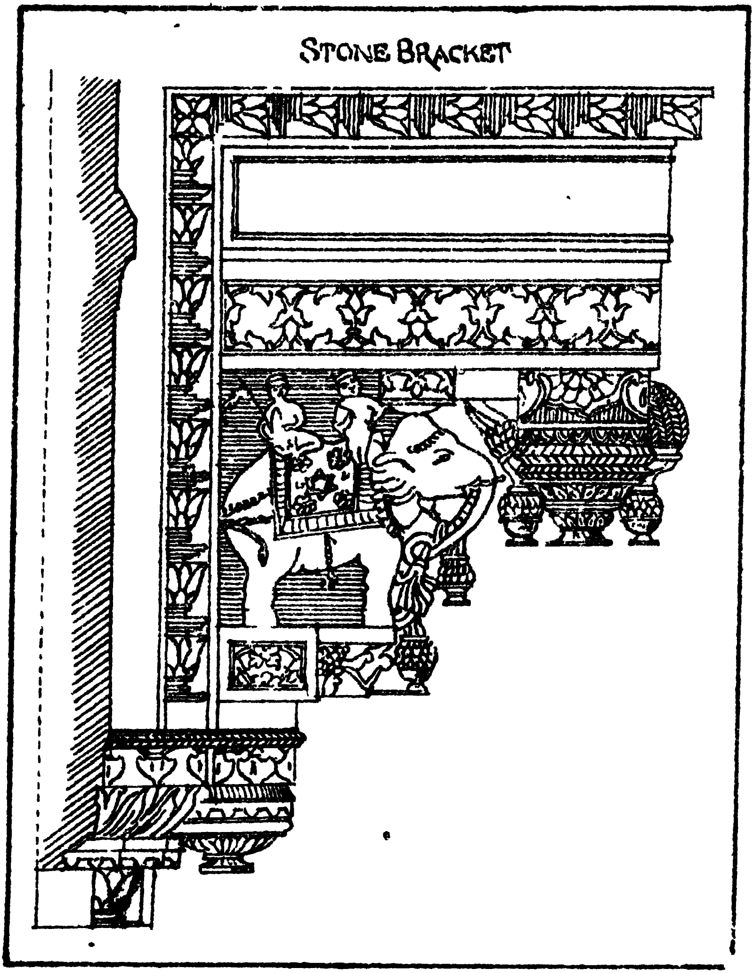

STONE BRACKET
SIDE ELEVATION
FRONT ELEVATION
H. REPRESENTS HOLLOW GROUND
H


STONE BRACKET
FRONT ELEVATION

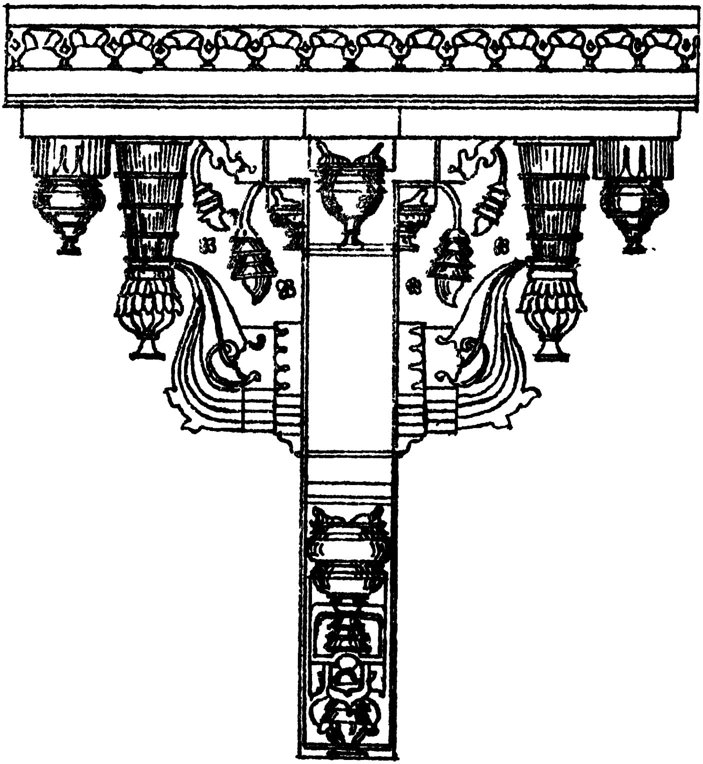

STONE BRACKET
FRONT ELEVATION
SIDE ELEVATION
H
H
H. Represents hollow ground

Stone Bracket.

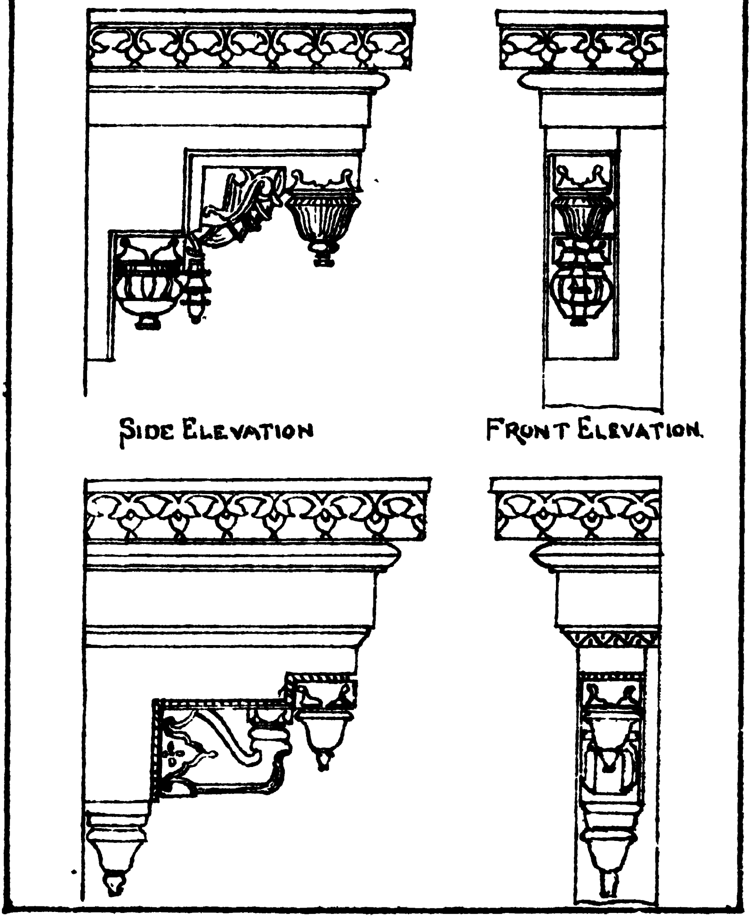


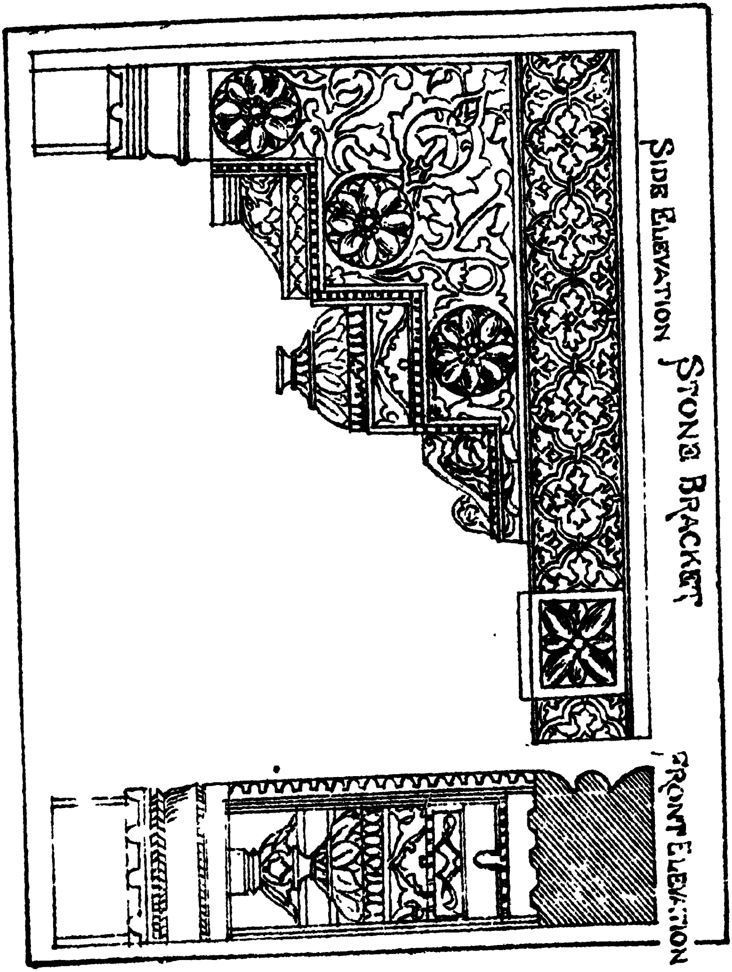

STONE BRACKET

STONE BRACKET



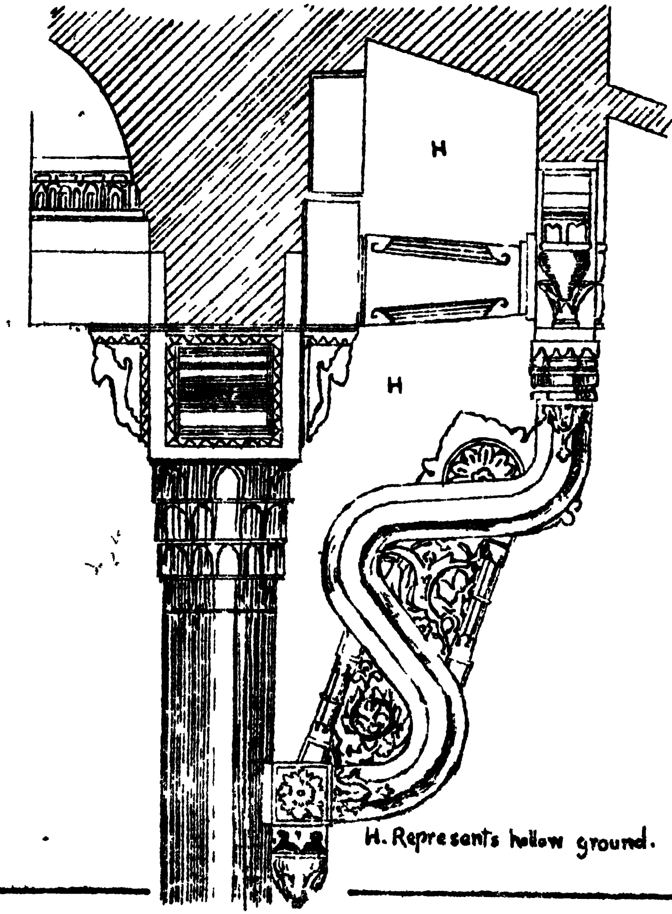
STONE BRACKETS



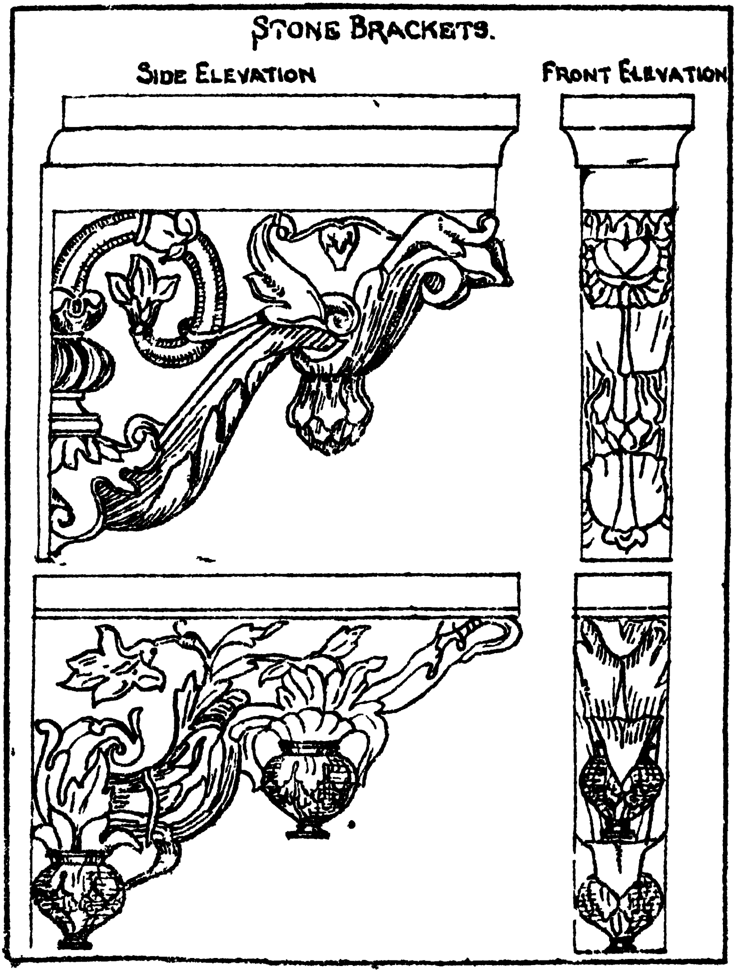


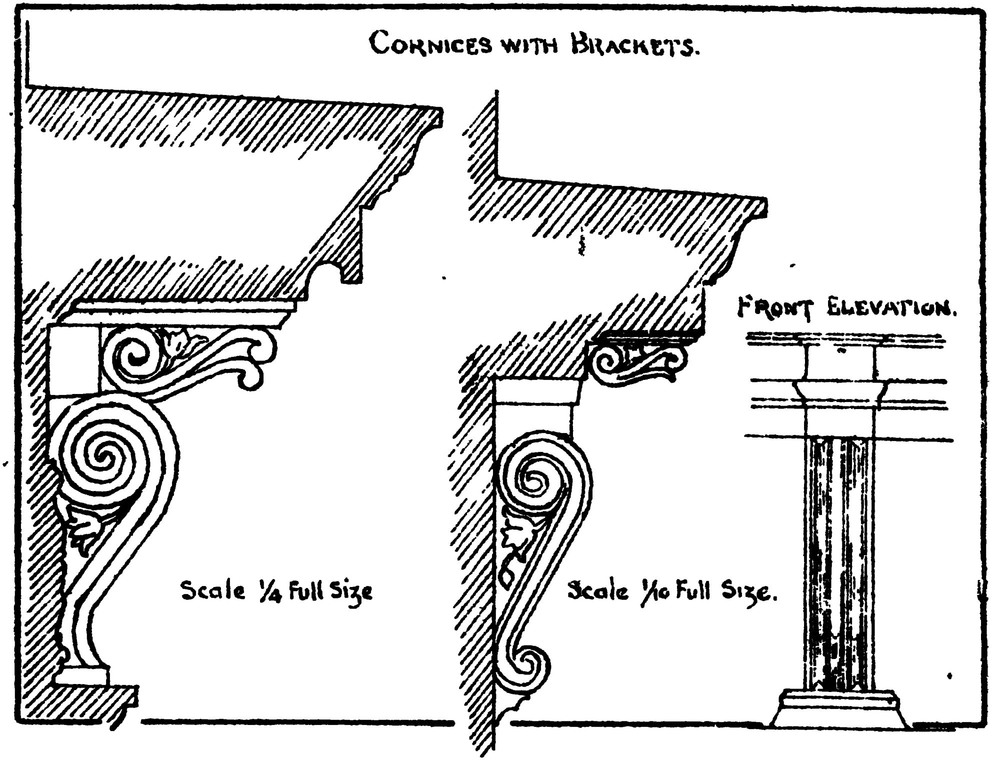
STONE BRACKET

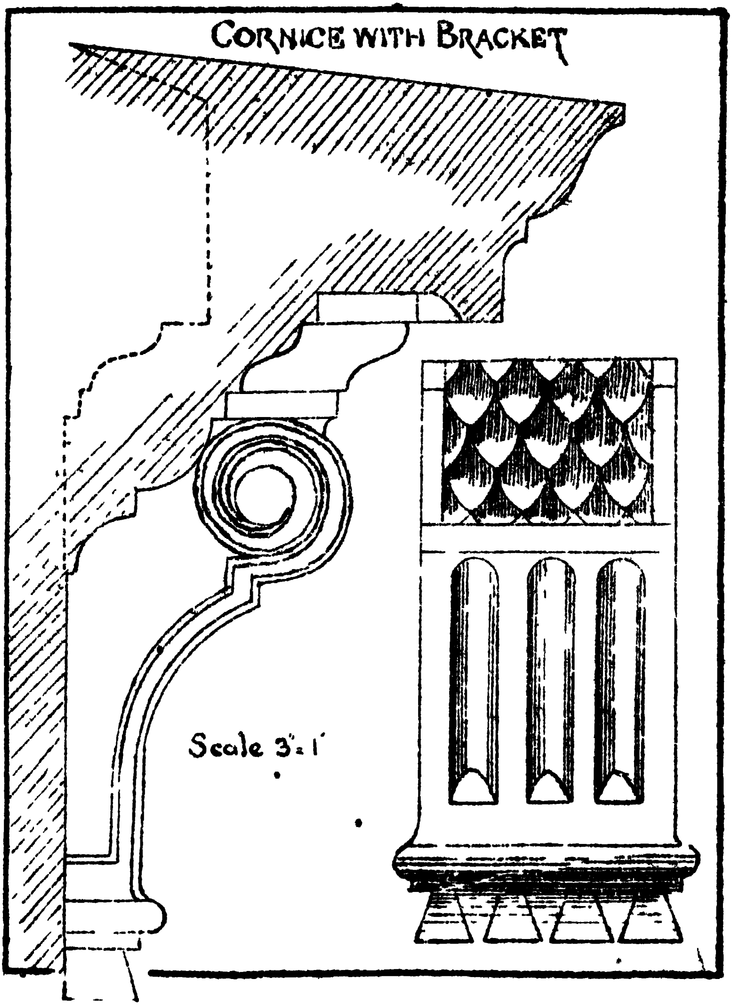
STONE BRACKET.

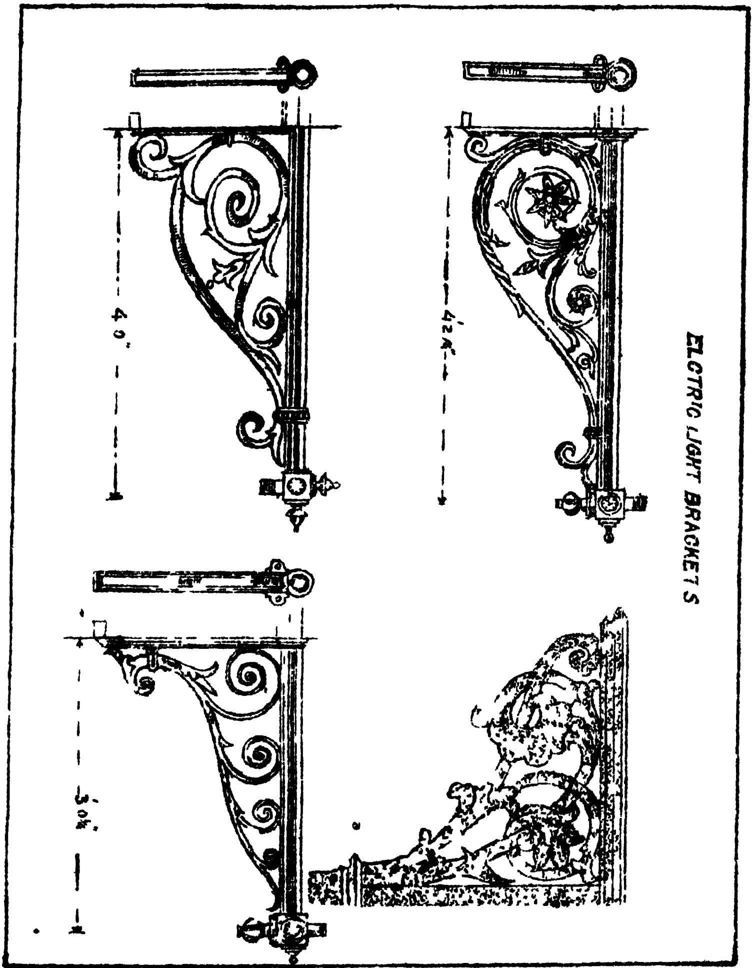


H. Represents hollow ground.

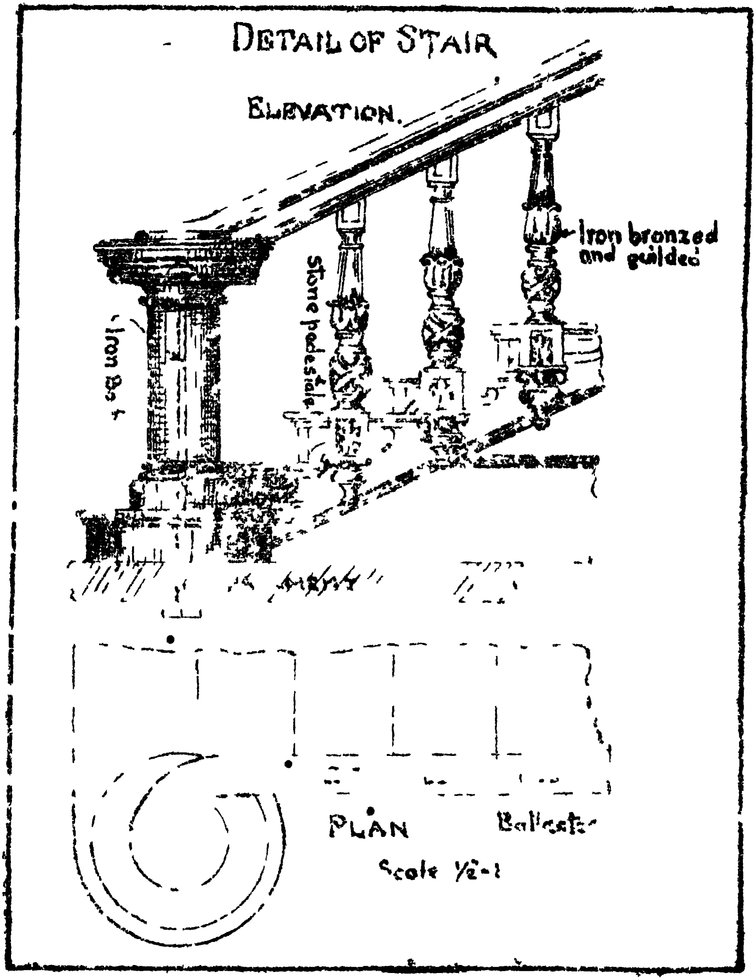

STONE BRACKETS.
SIDE ELEVATION
FRONT ELEVATION

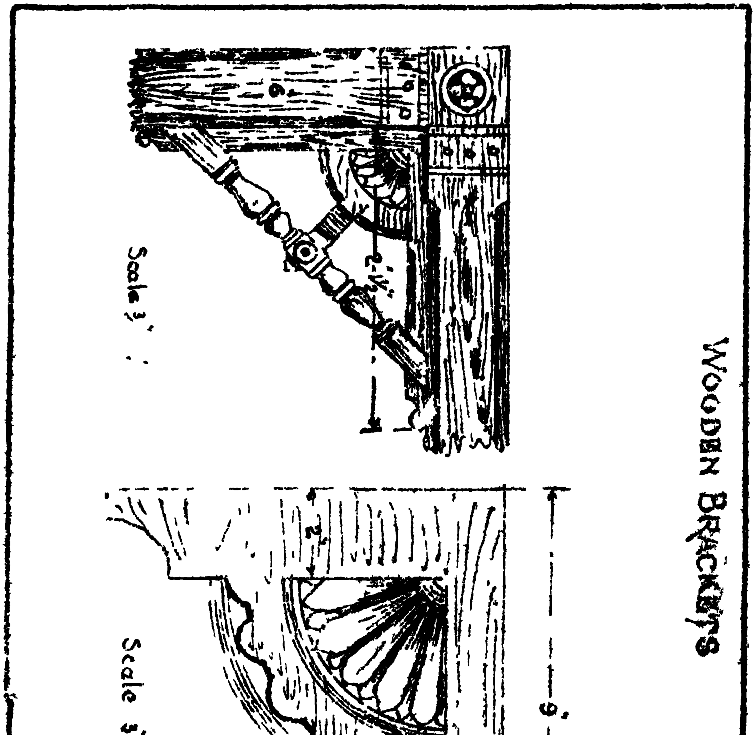

CORNICES WITH BRACKETS.
Scale 1/4 Full Size
Scale 1/10 Full Size.
FRONT ELEVATION.

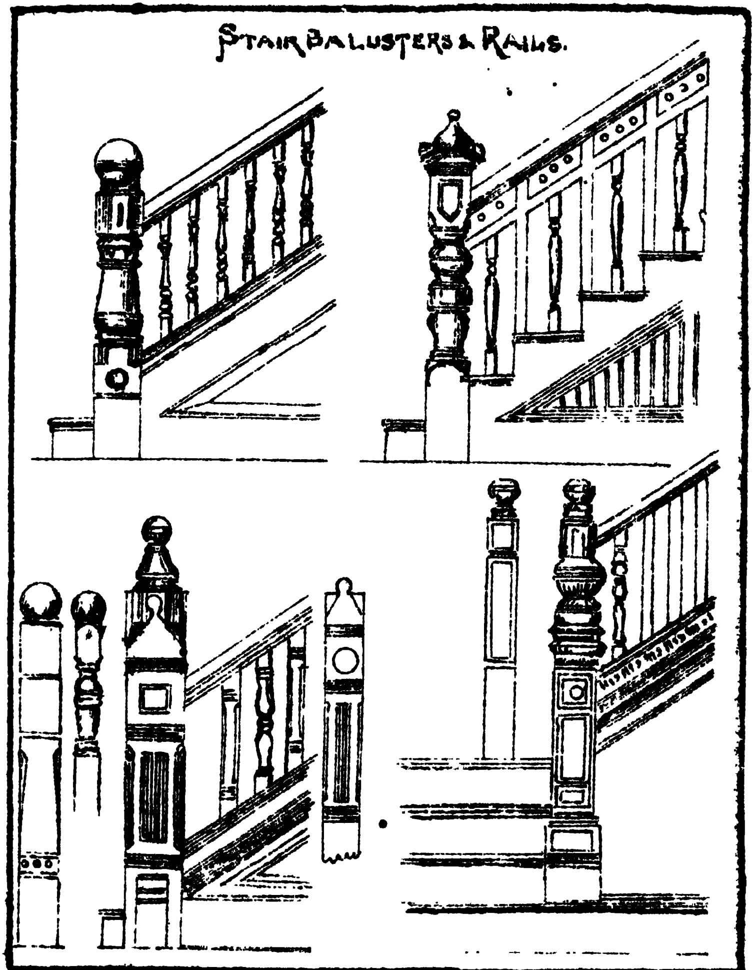

CORNICE WITH BRACKET
Scale 3" = 1'



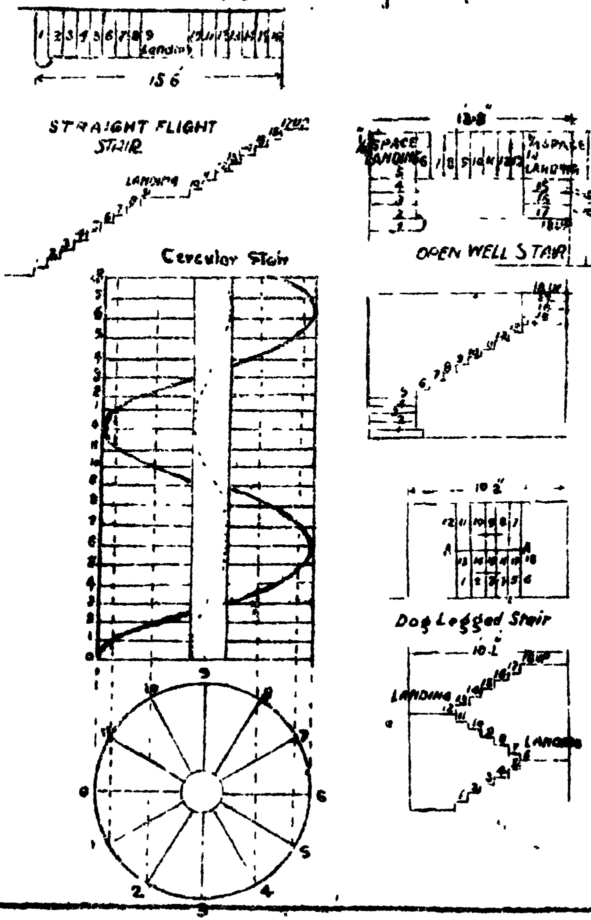
ELCTRIC LIGHT BRACKETS

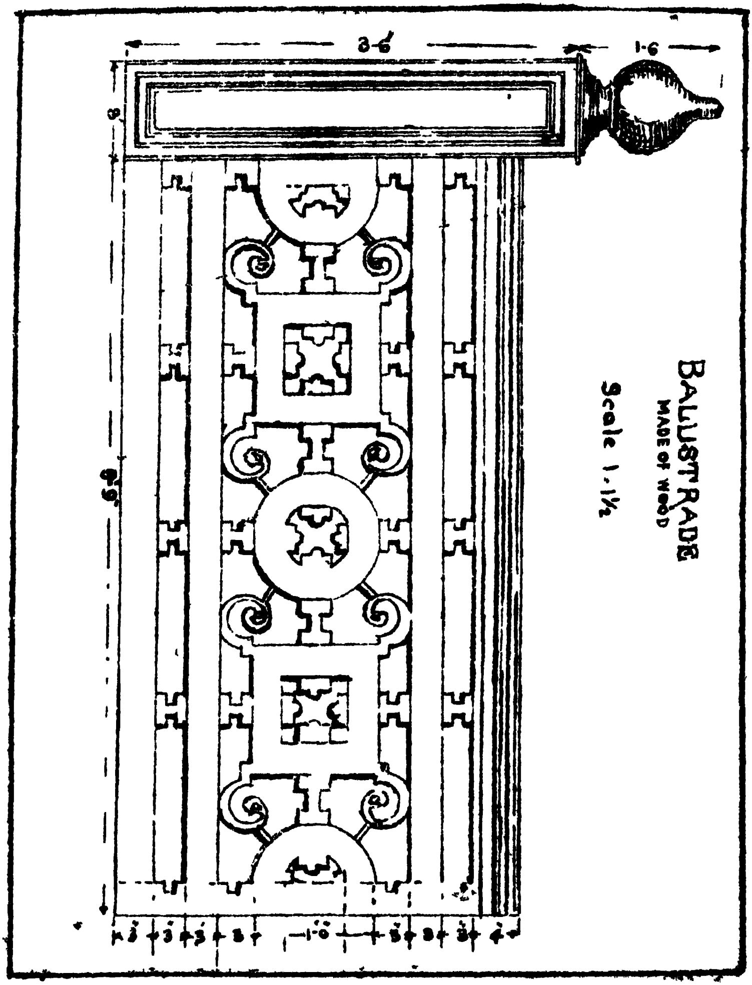

DETAIL OF STAIR
ELEVATION.
Iron bronzed
and guilded
Stone pedestals
Iron Post
PLAN
Scale 1/2"=1

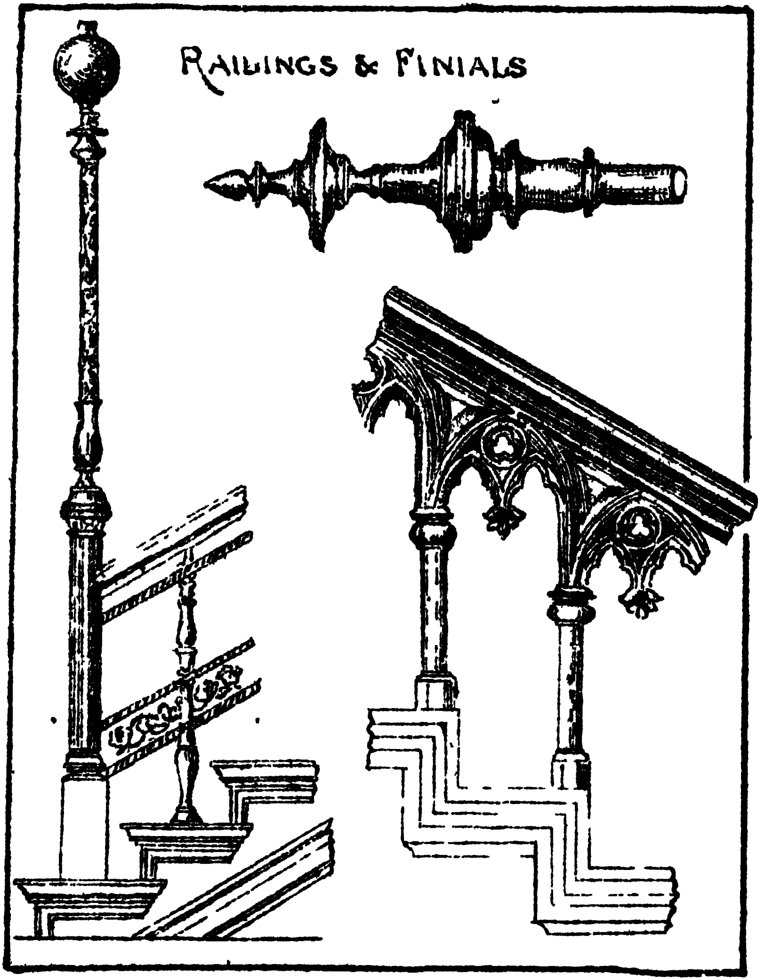

WOODEN BRACKETS
Scale 3:1
9"

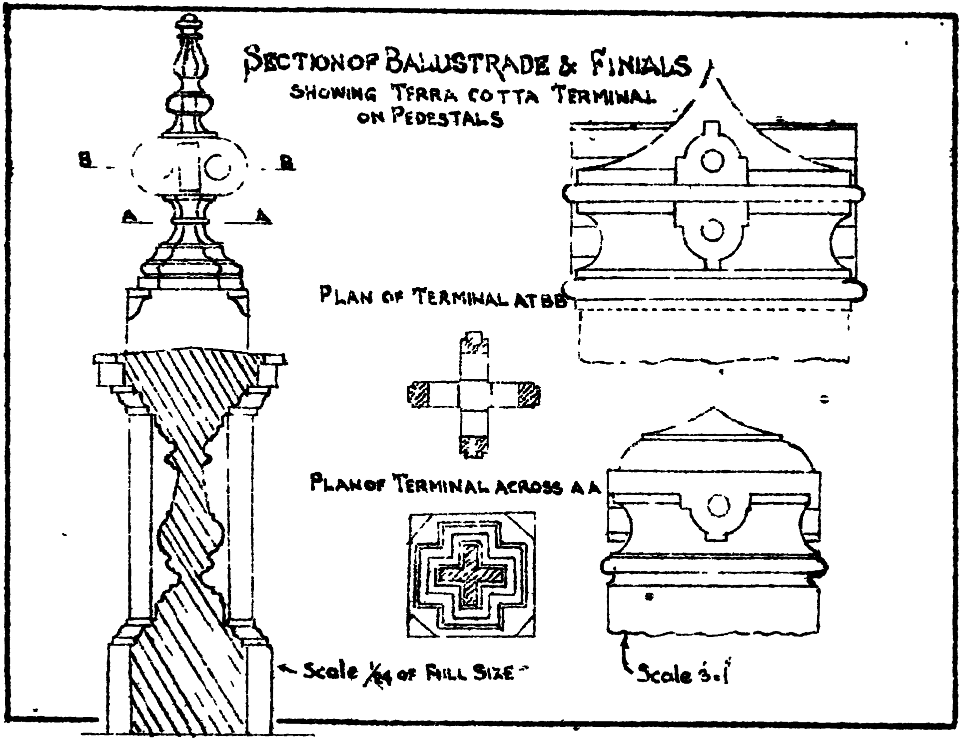

STAIR BALUSTERS & RAILS.

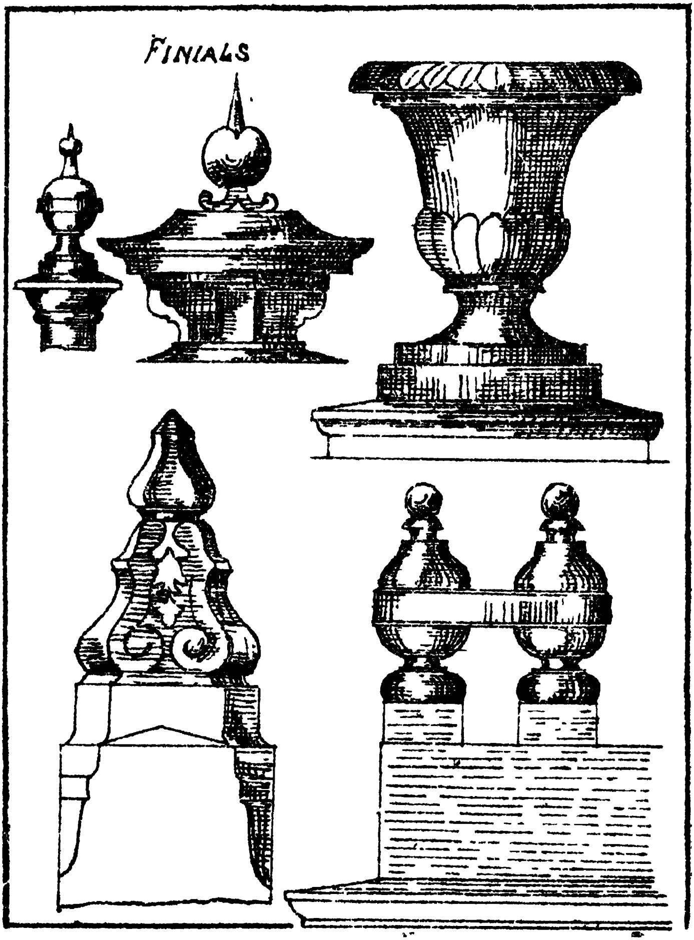
TYPES OF STAIRS

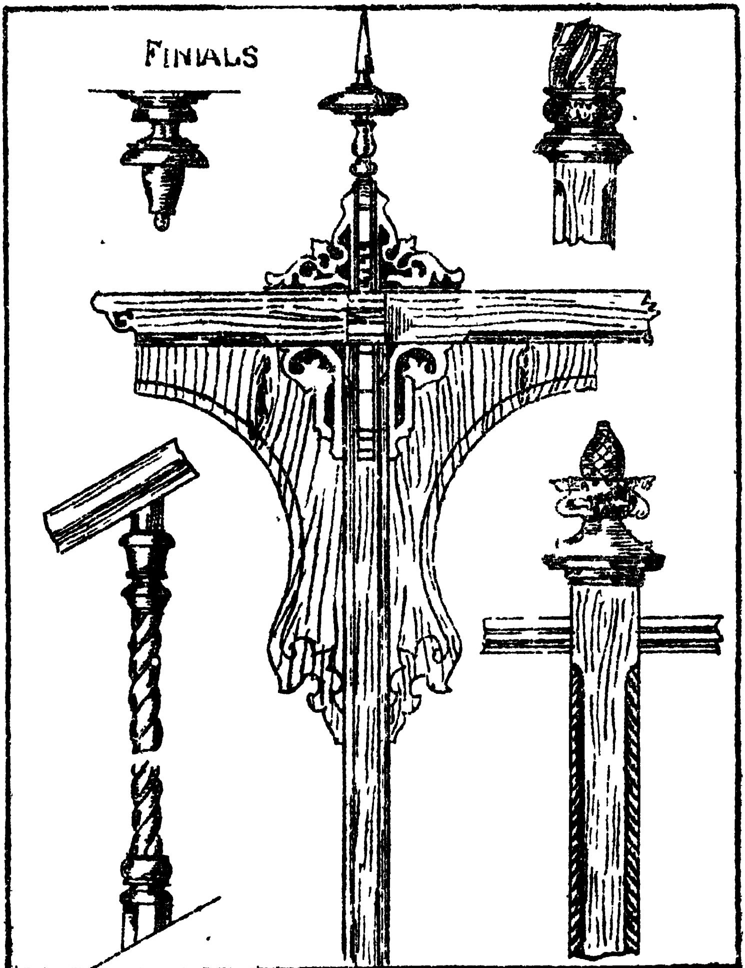


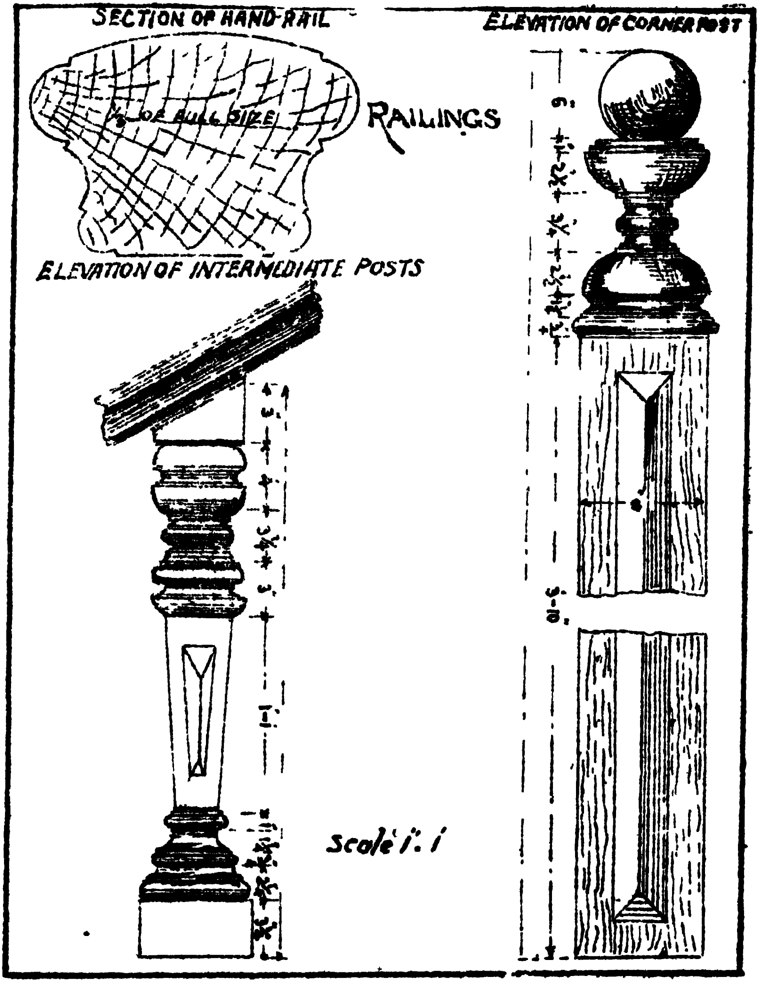

BALUSTRADE
MADE OF WOOD
Scale 1-1½


RAILINGS & FINIALS

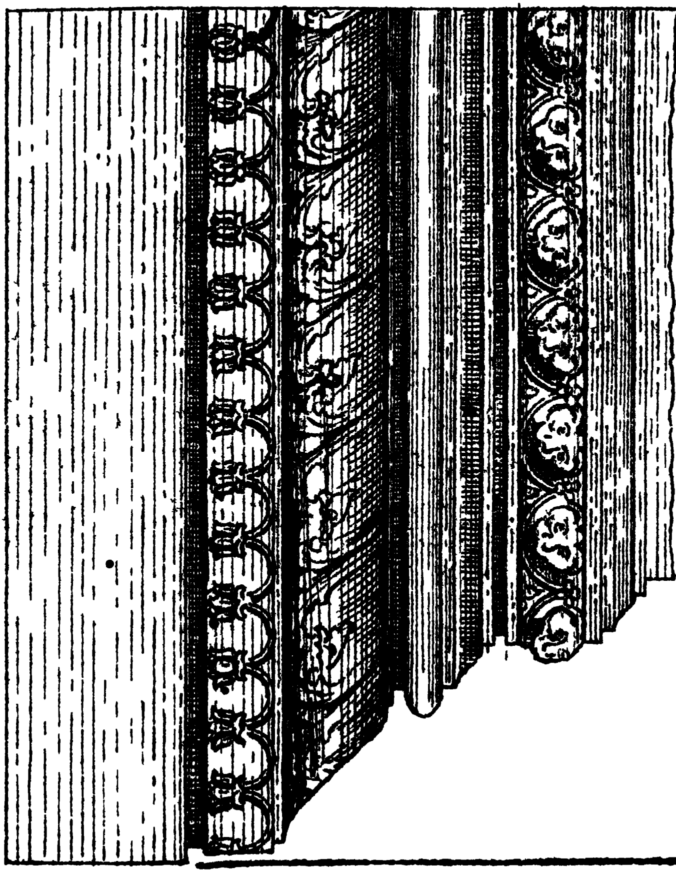

SECTION OF BALUSTRADE & FINIALS
SHOWING TERRA COTTA TERMINAL
ON PEDESTALS
B
B
A
A
PLAN OF TERMINAL AT BB
PLAN OF TERMINAL ACROSS A A
Scale 1/24 OF FULL SIZE
Scale 3:1

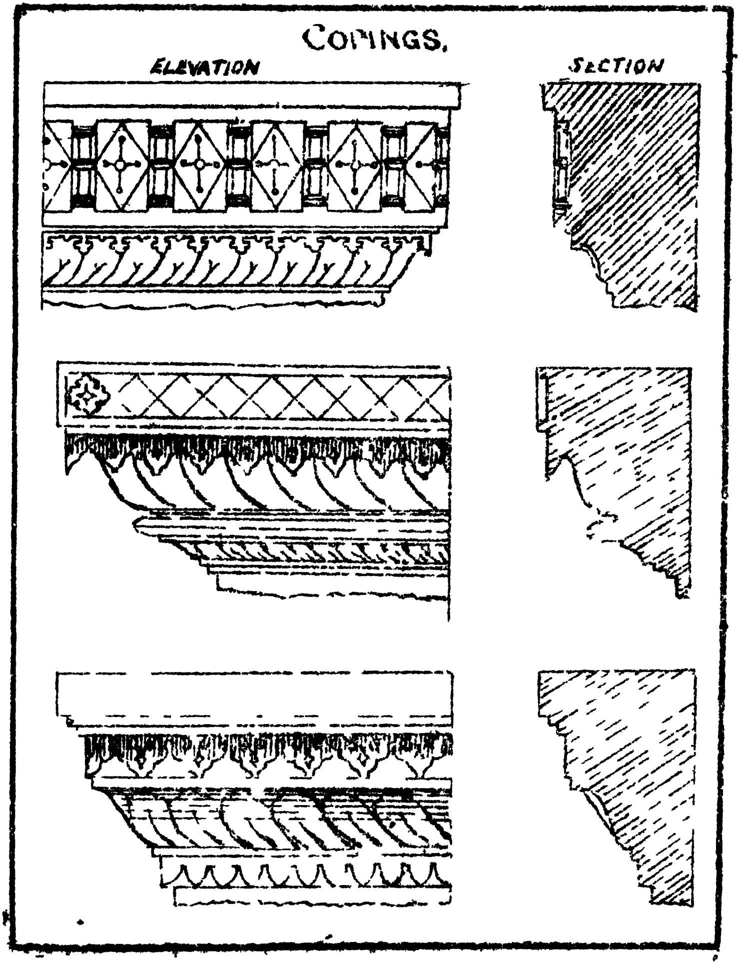

FINIALS

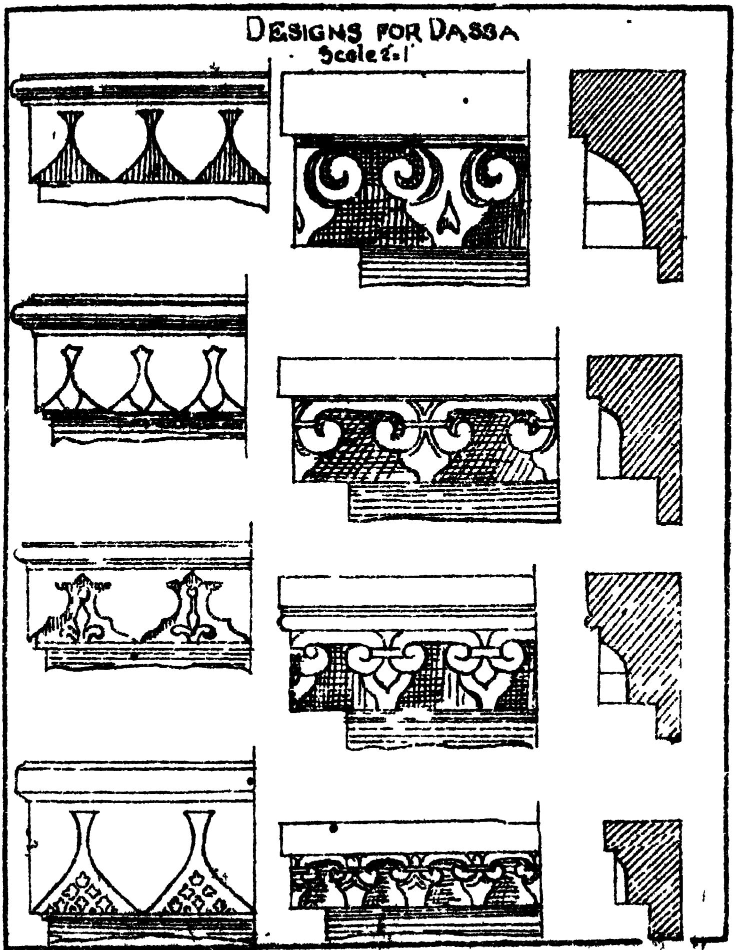

FINIALS

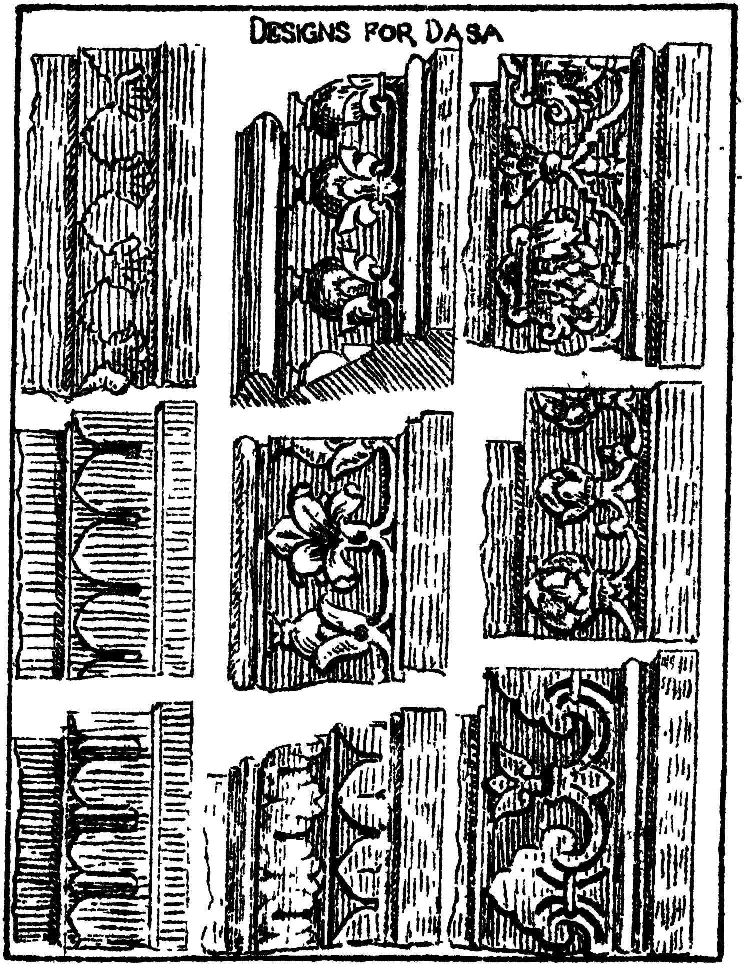

SECTION OF HAND-RAIL
ELEVATION OF CORNER POST
½ OF FULL SIZE
RAILINGS
ELEVATION OF INTERMEDIATE POSTS
Scale 1": 1'

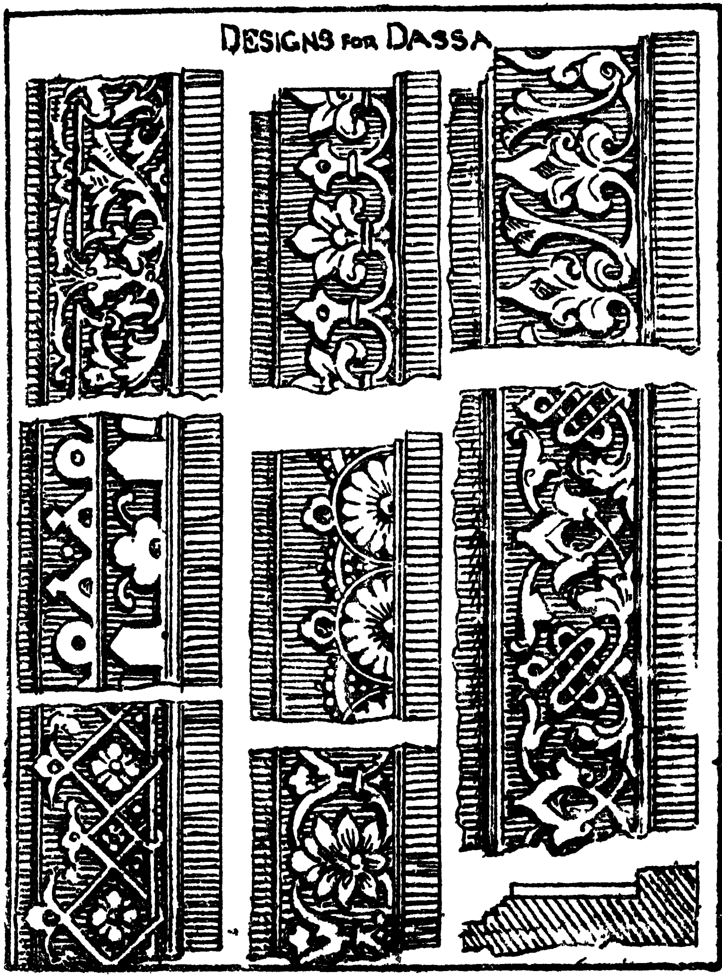
ORNAMENTAL STONE PLINTH



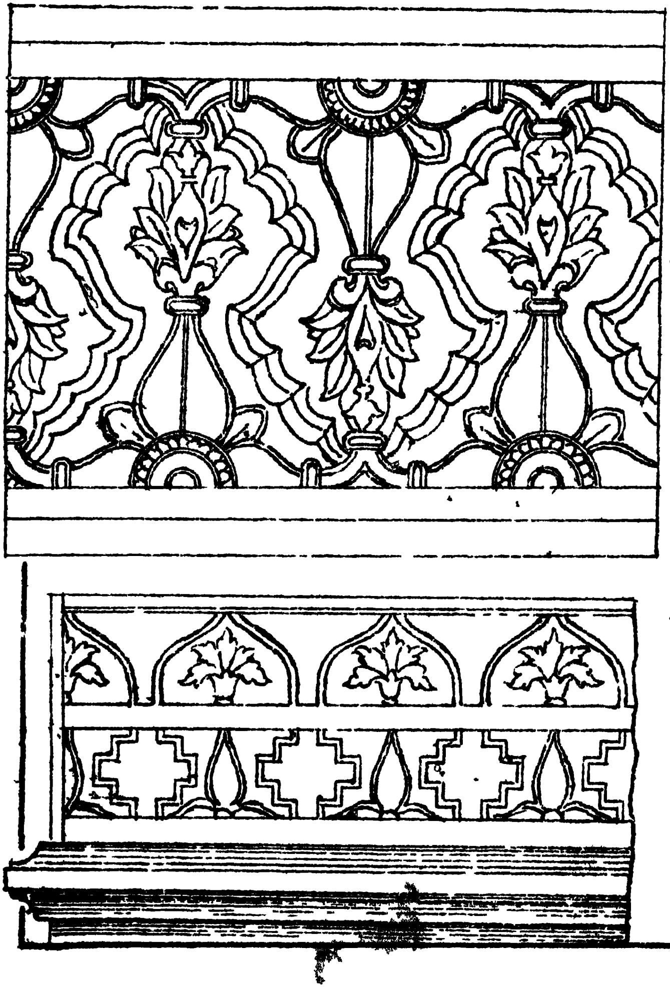

COPINGS.
ELEVATION
SECTION


DESIGNS FOR DASSA
Scale 2:1


DESIGNS FOR DASA

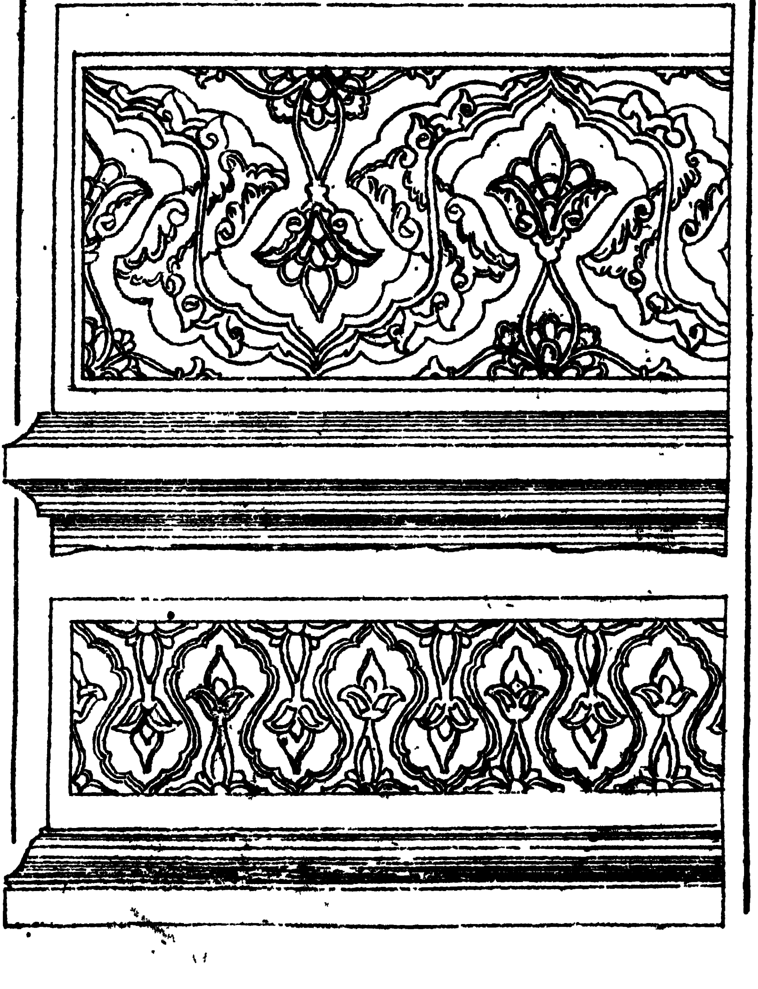

DESIGNS FOR DASSA

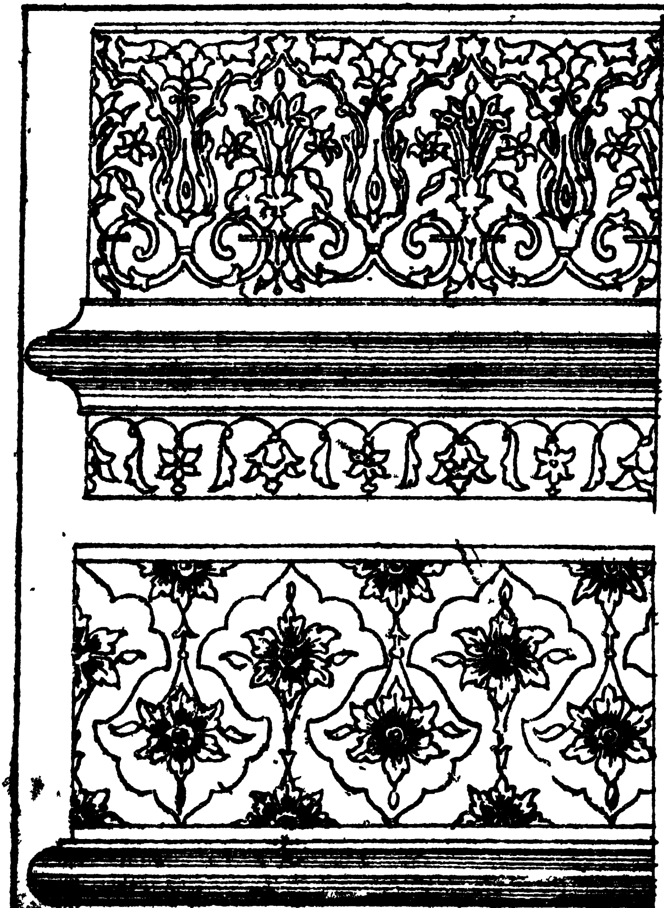
178



ORNAMENTAL WORK ON PARAPETS

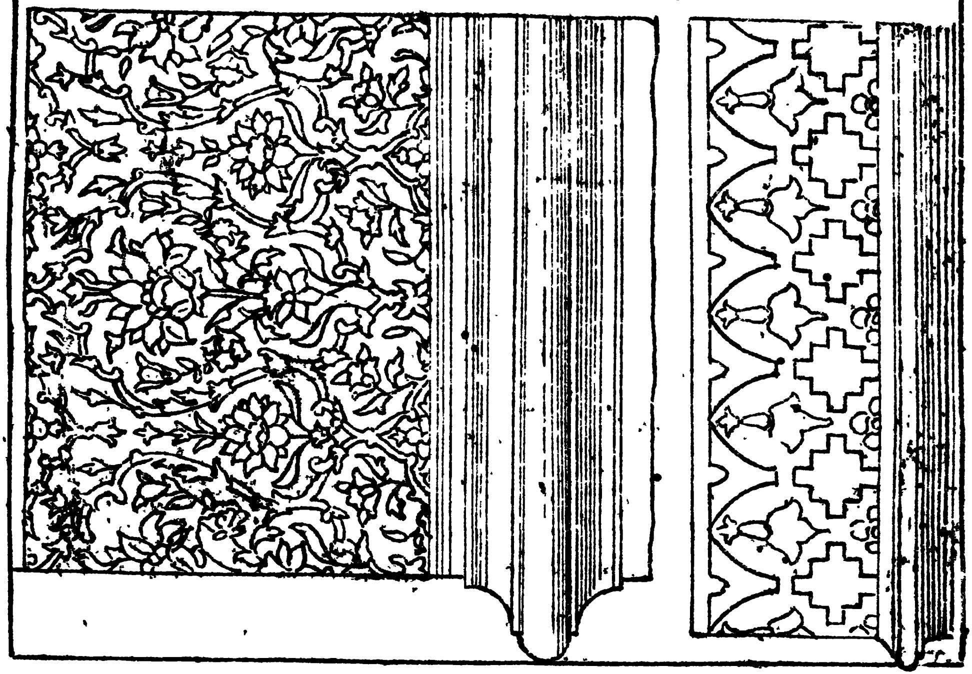
ORNAMENTAL WORK ON PARAPETS.

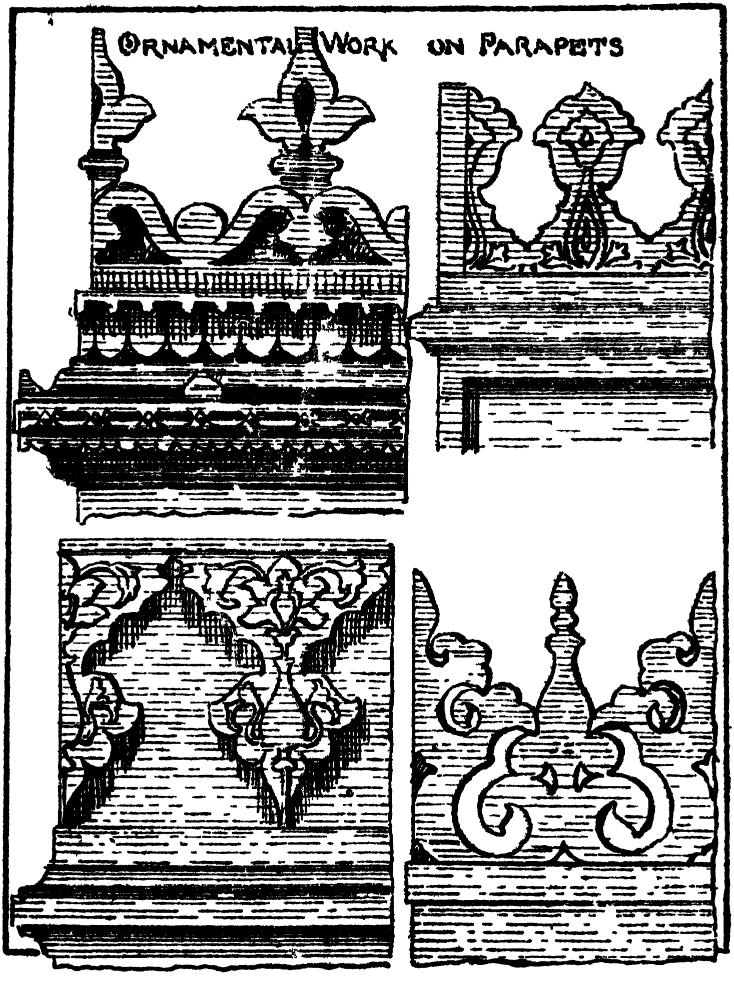


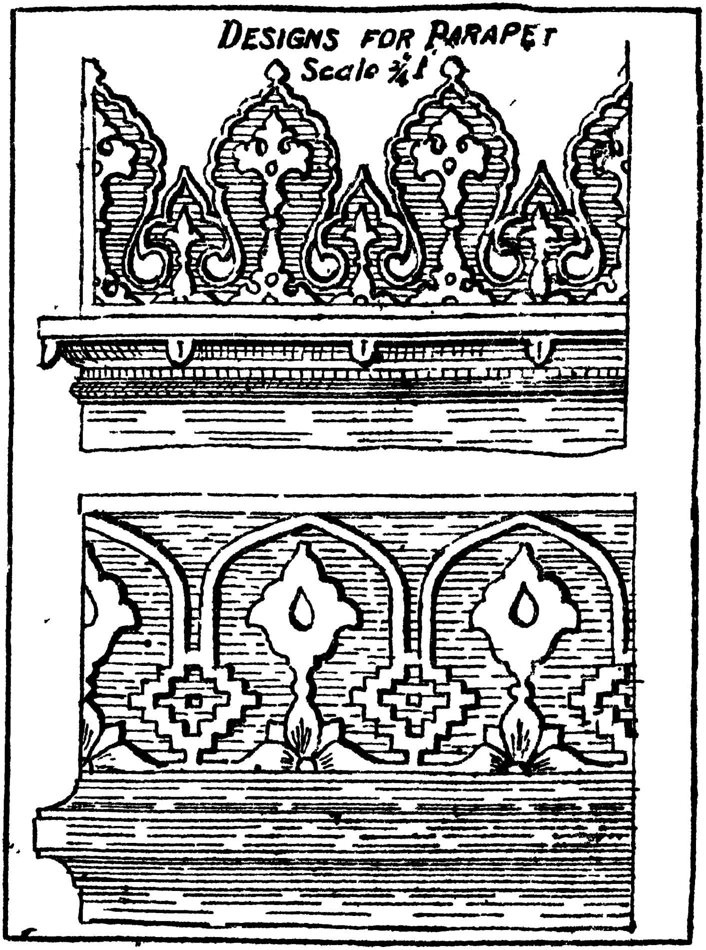


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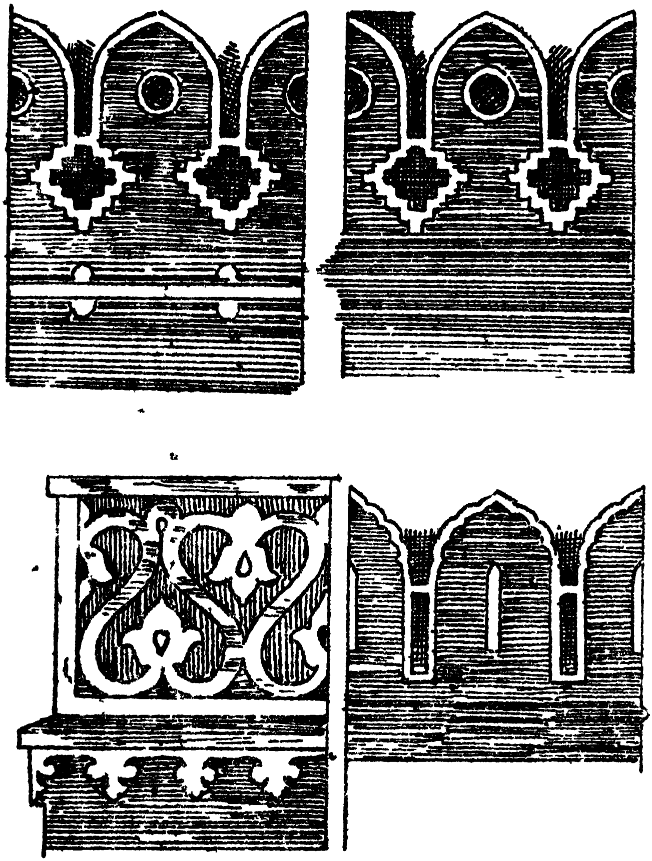
ORNAMENTAL WORK PARAPET

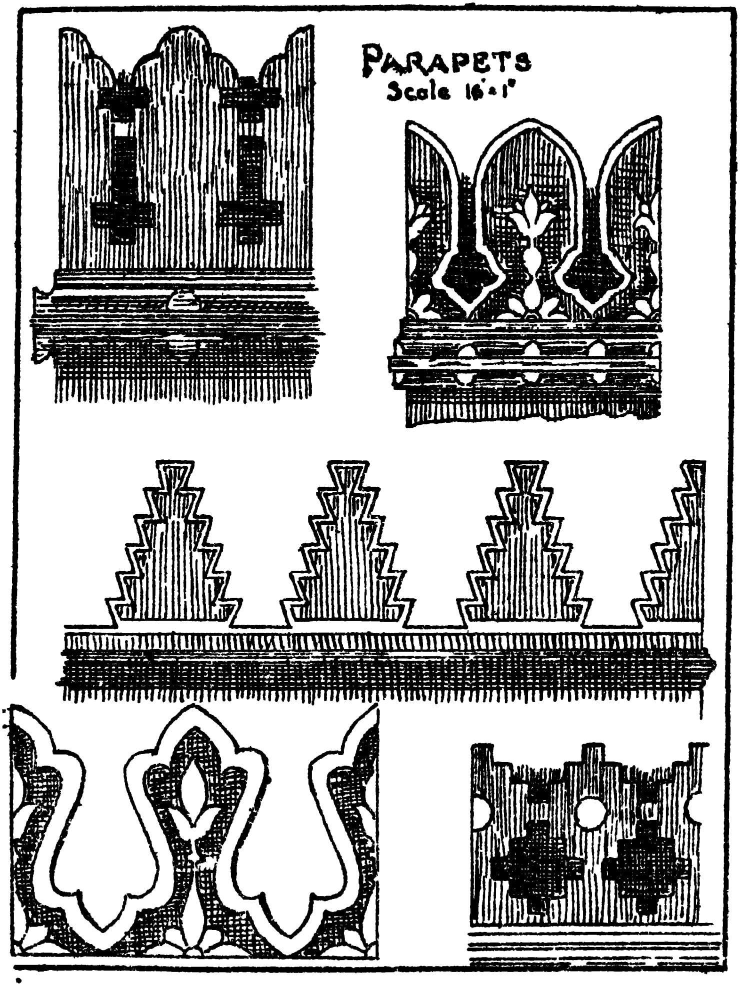



ORNAMENTAL WORK ON PARAPETS

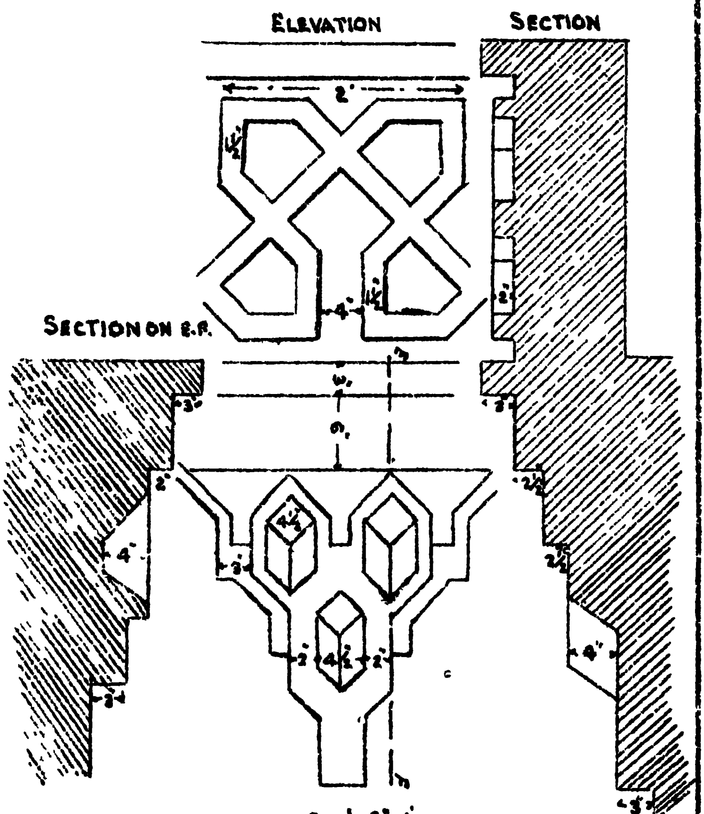

DESIGNS FOR PARAPET
Scale ¾" 1'

Parapets.

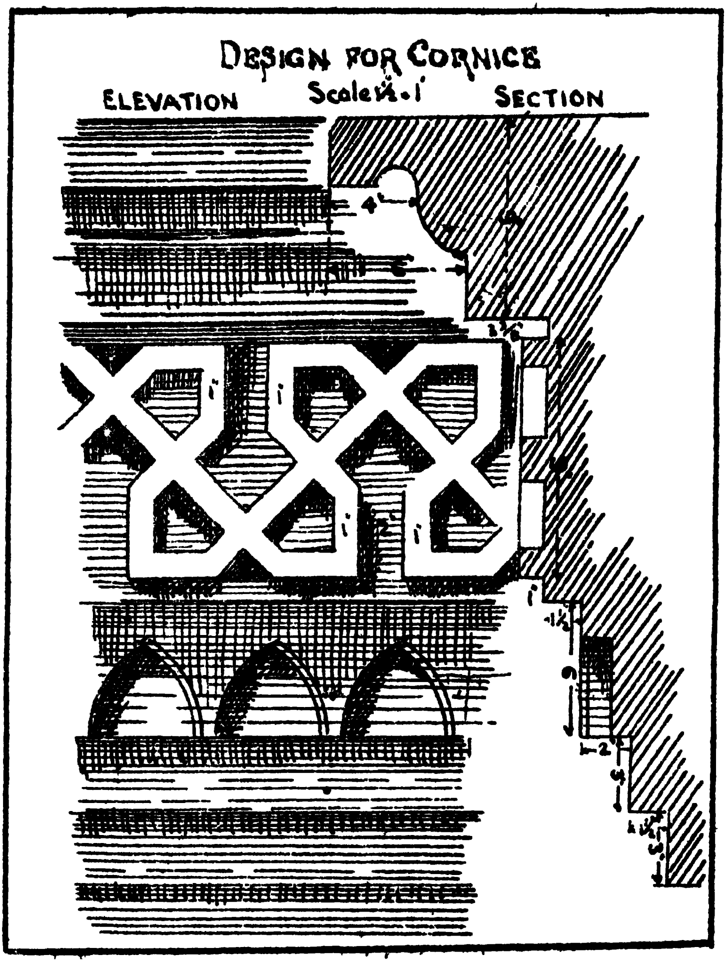



PARAPETS
Scale 16'=1"

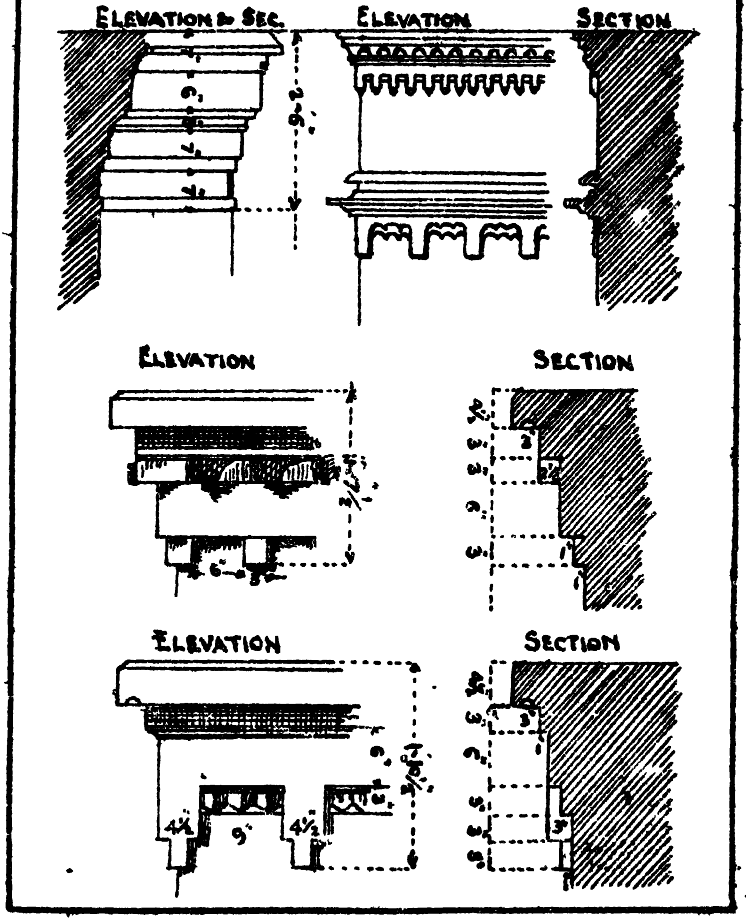
DETAIL CORNICE WITH PARAPET

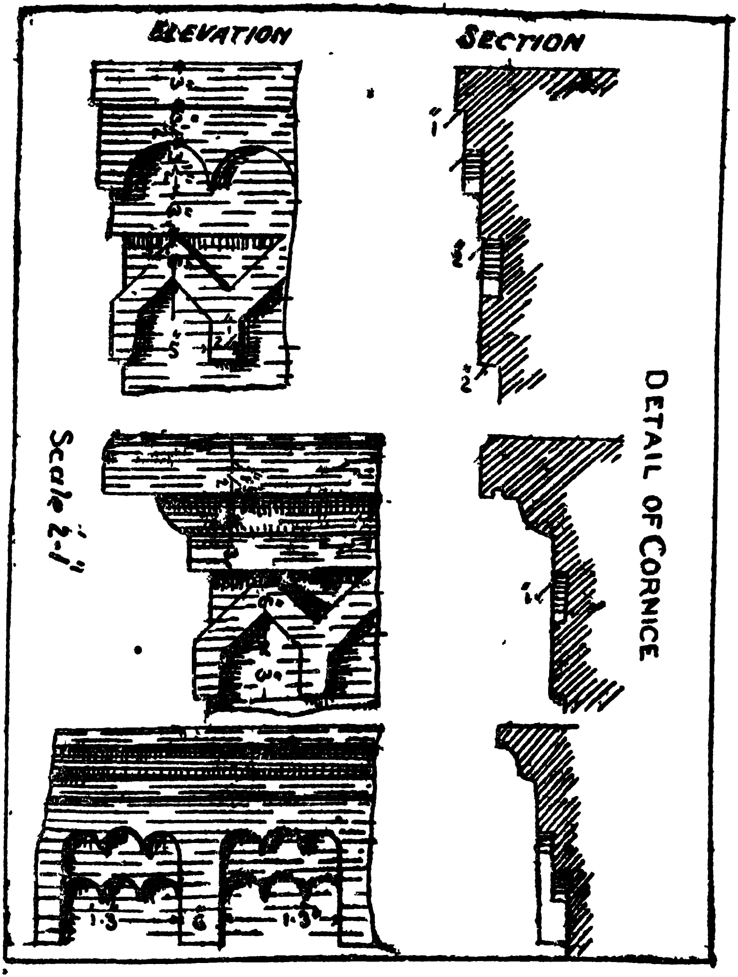


Scale ¾" = 1'

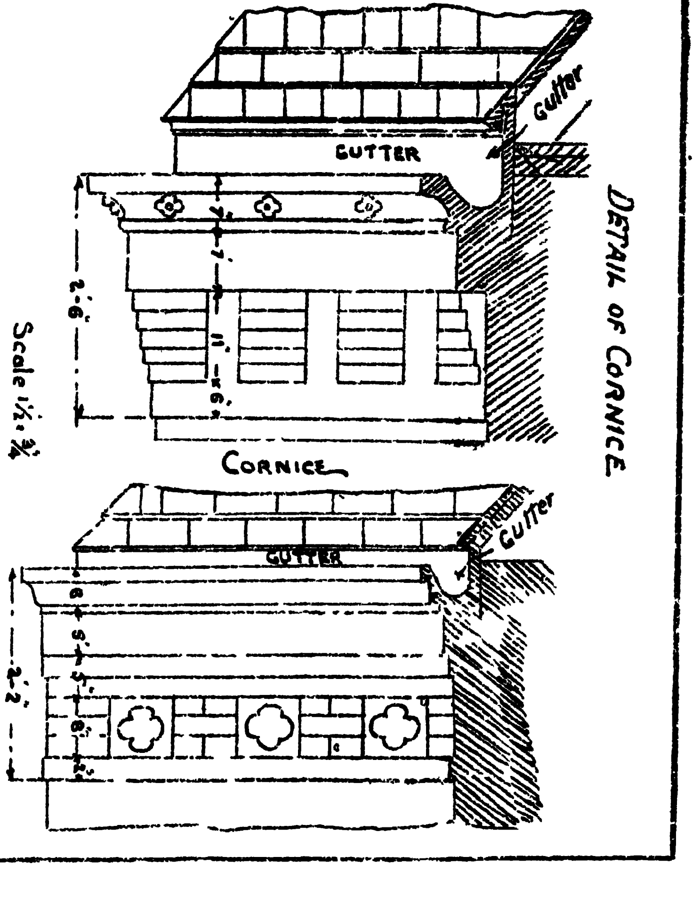

DESIGN FOR CORNICE
ELEVATION
Scale ½.1'
SECTION

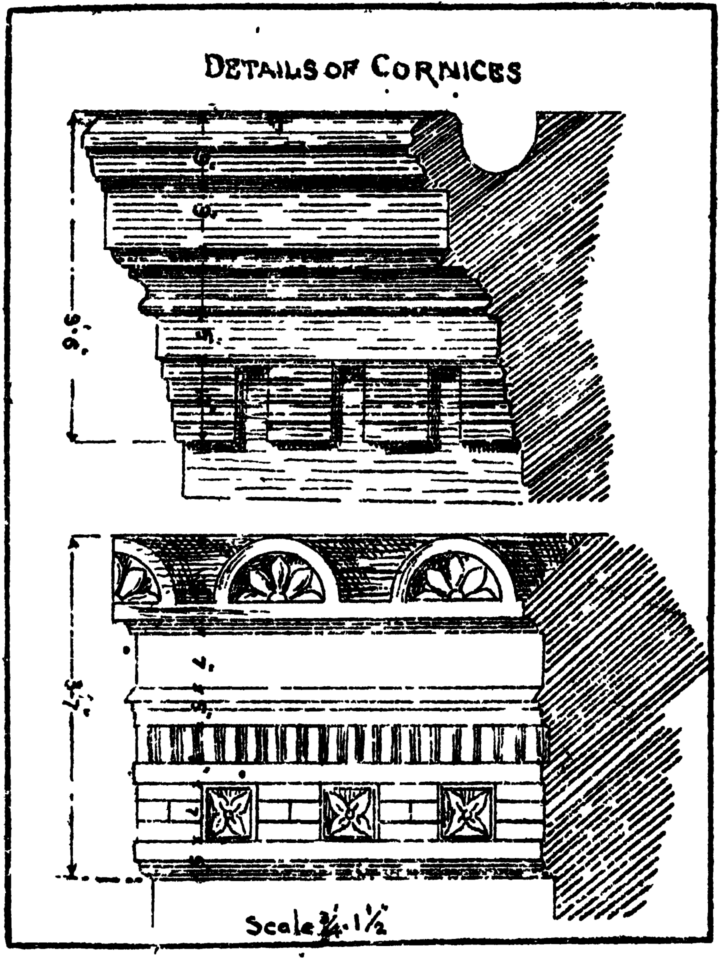
Cornices

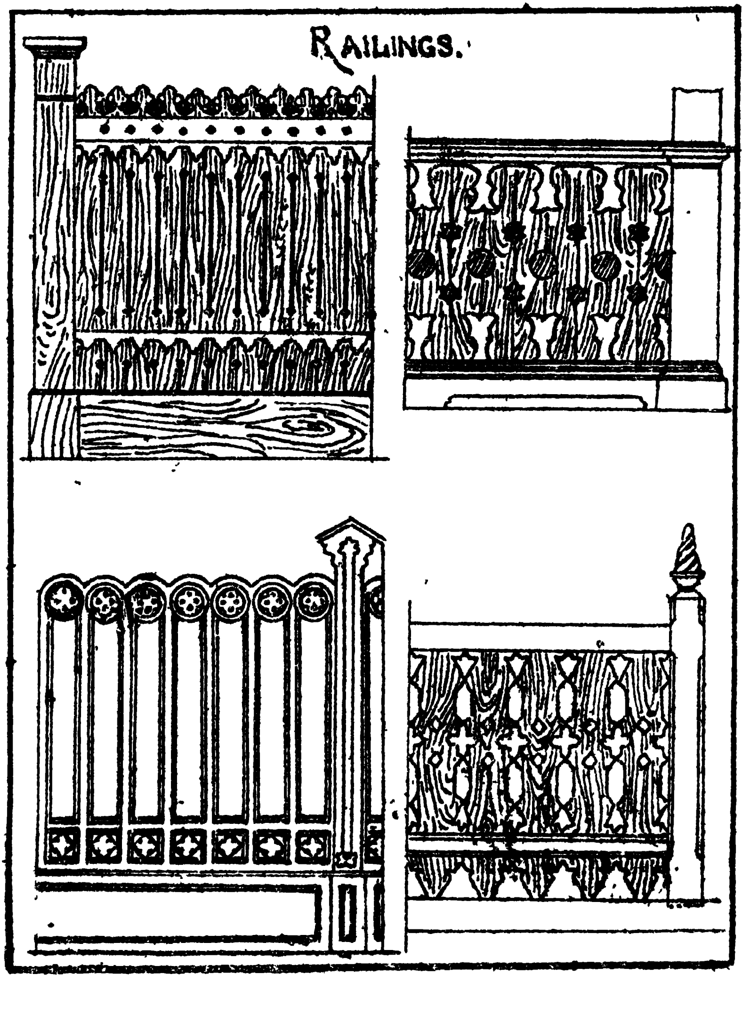

Elevation & Sec.
Elevation
Section
Elevation
Section
Elevation
Section
4½″
9″
4½″

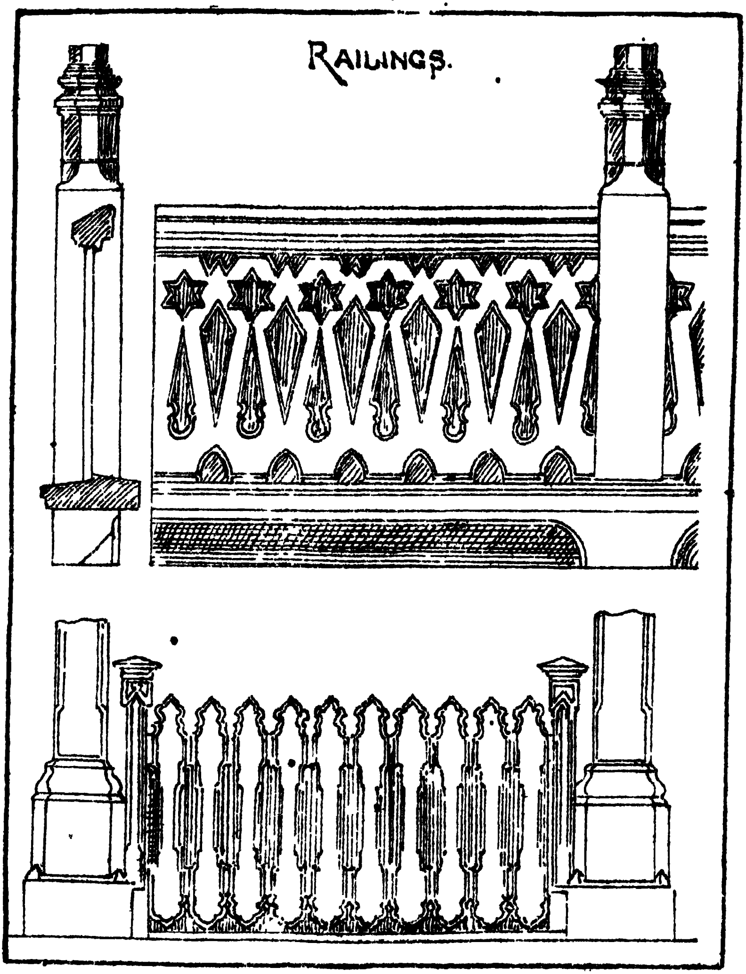

ELEVATION
SECTION
DETAIL OF CORNICE

DETAILS OF CORNICES.



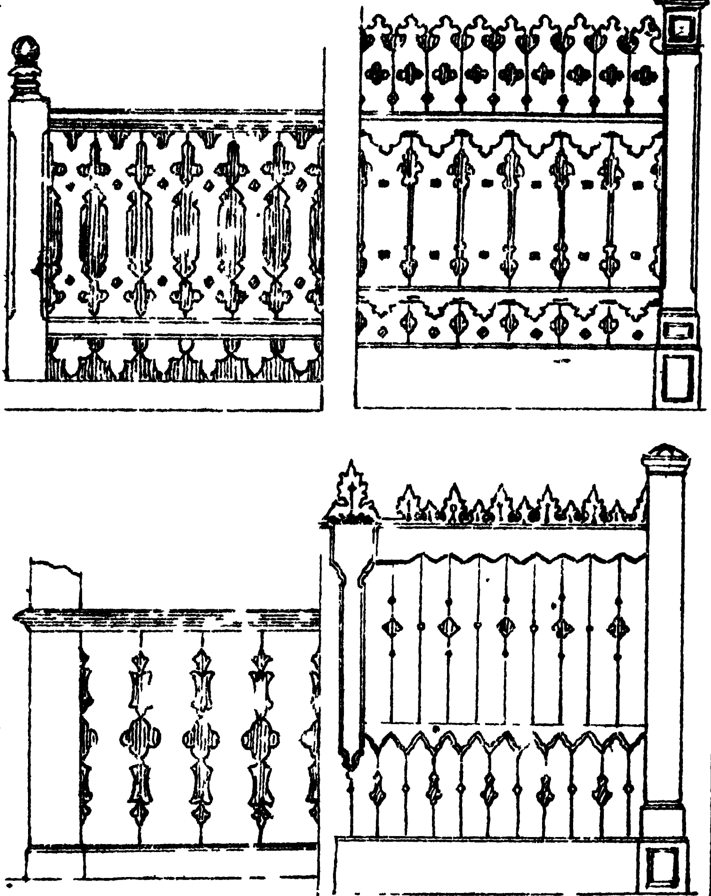

DETAILS OF CORNICES
Scale ¾ · 1½

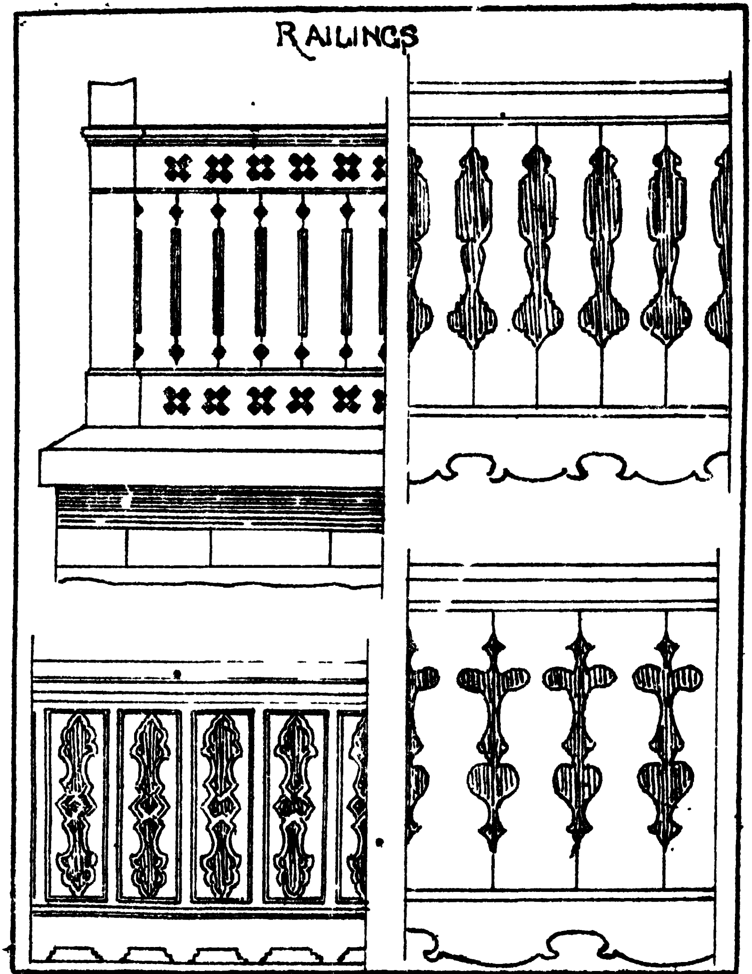

RAILINGS.



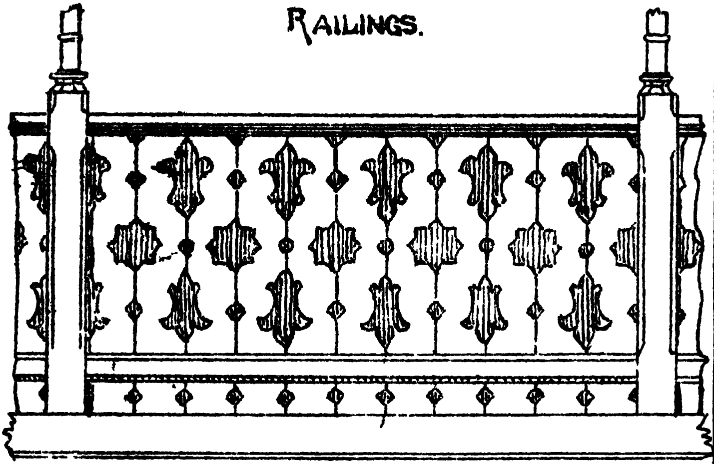
RAILINGS.

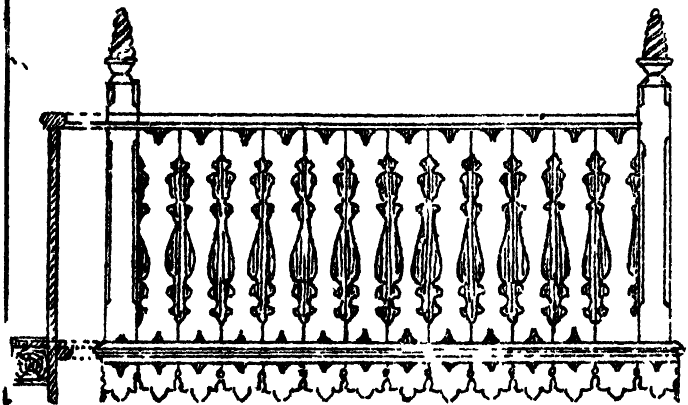
RAILINGS

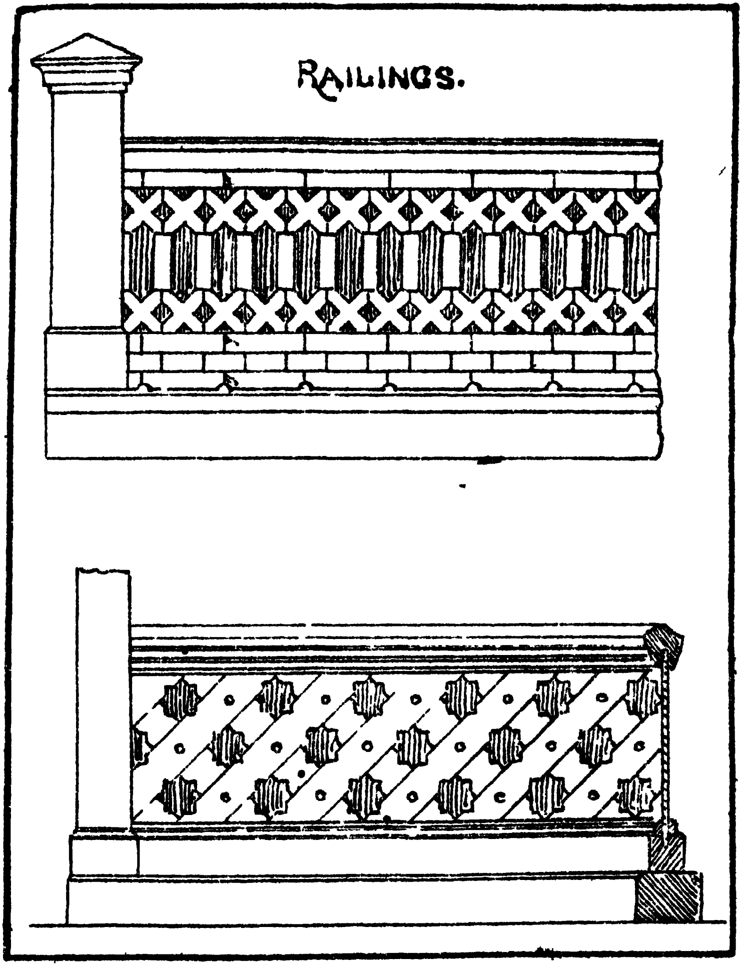



RAILINGS

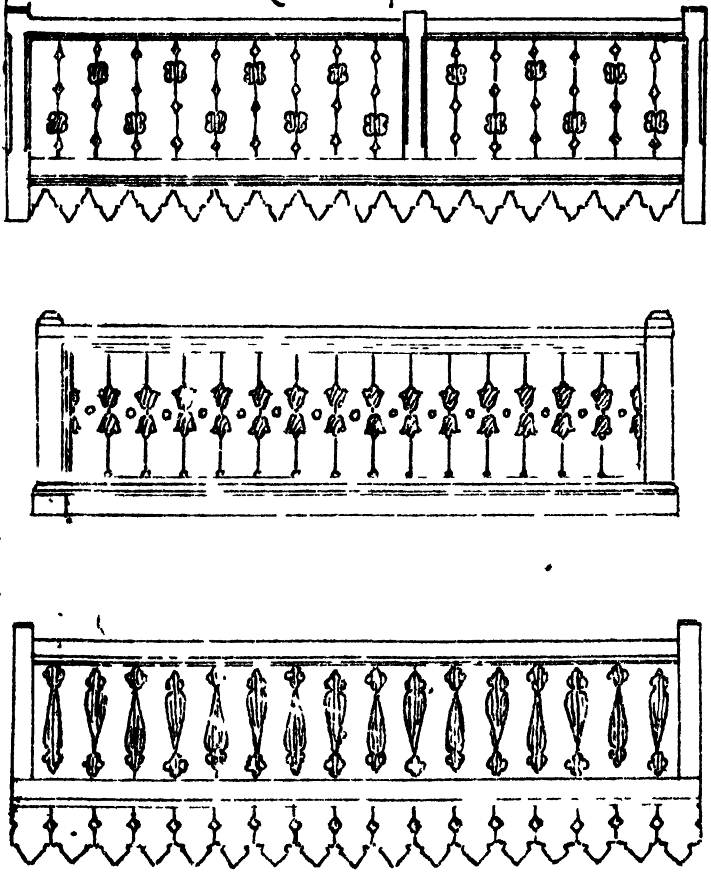
RAILINGS.



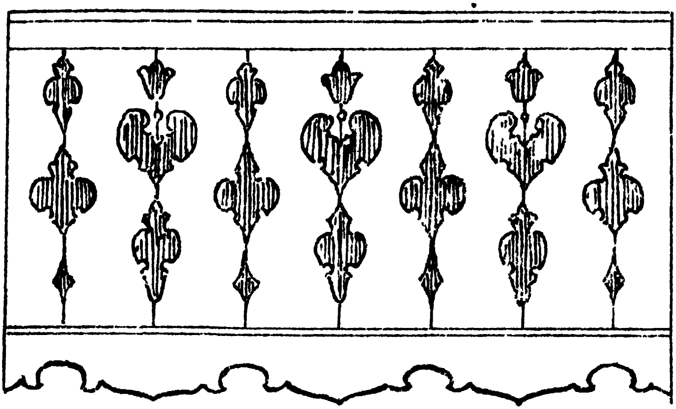


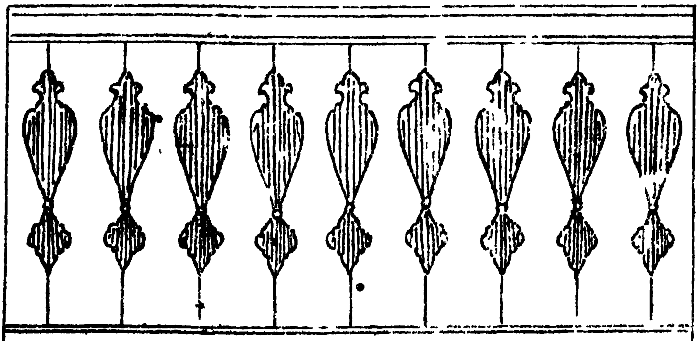

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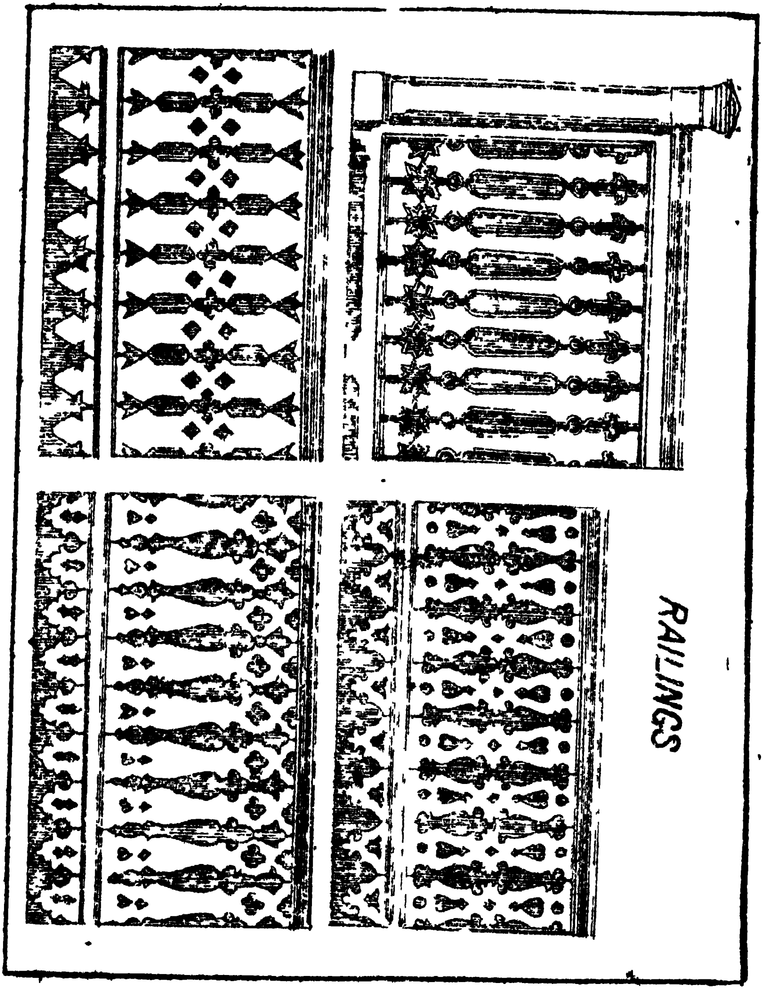
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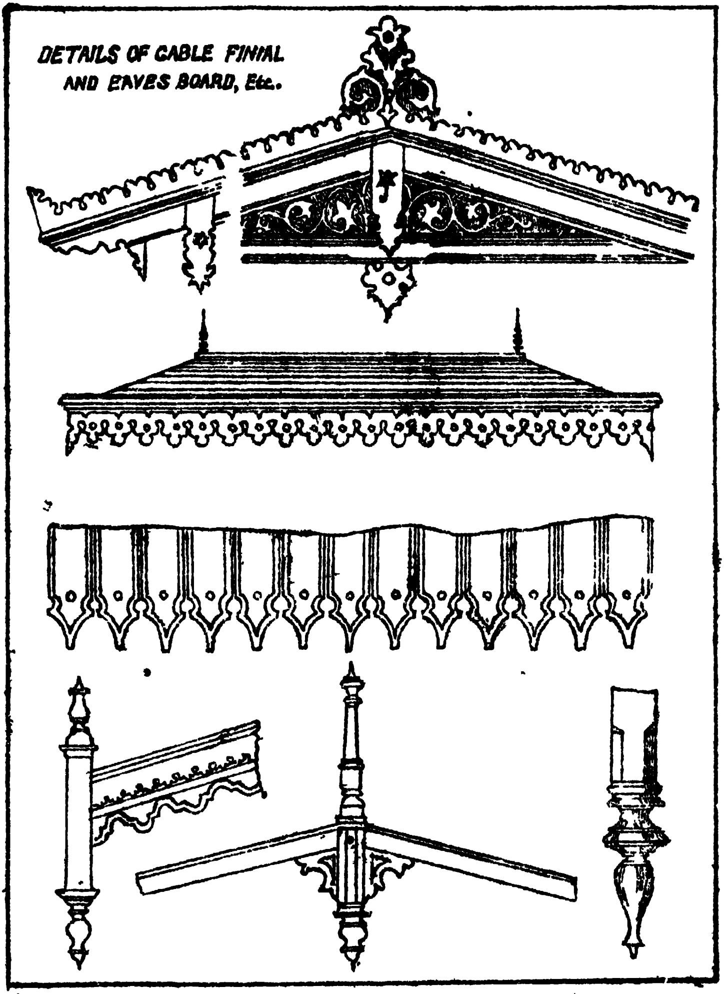


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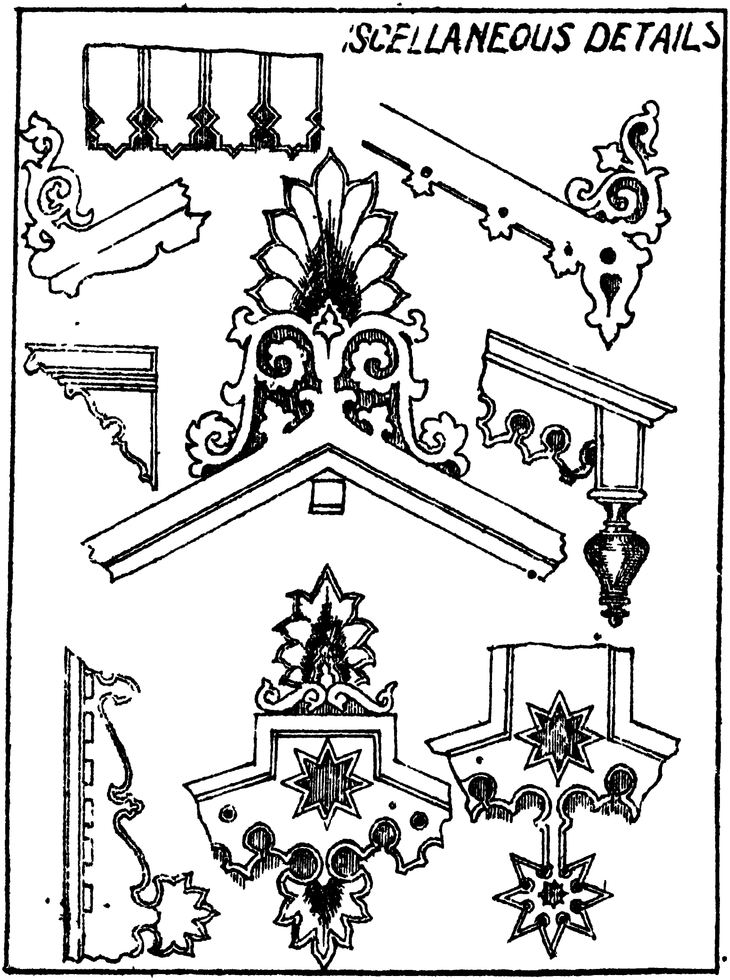


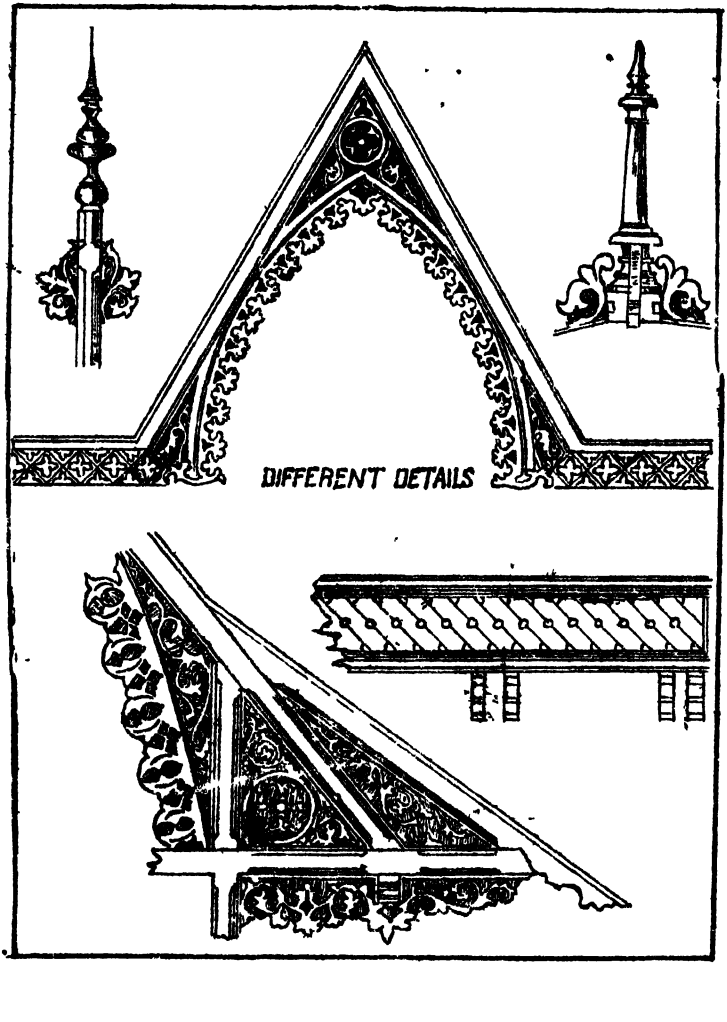


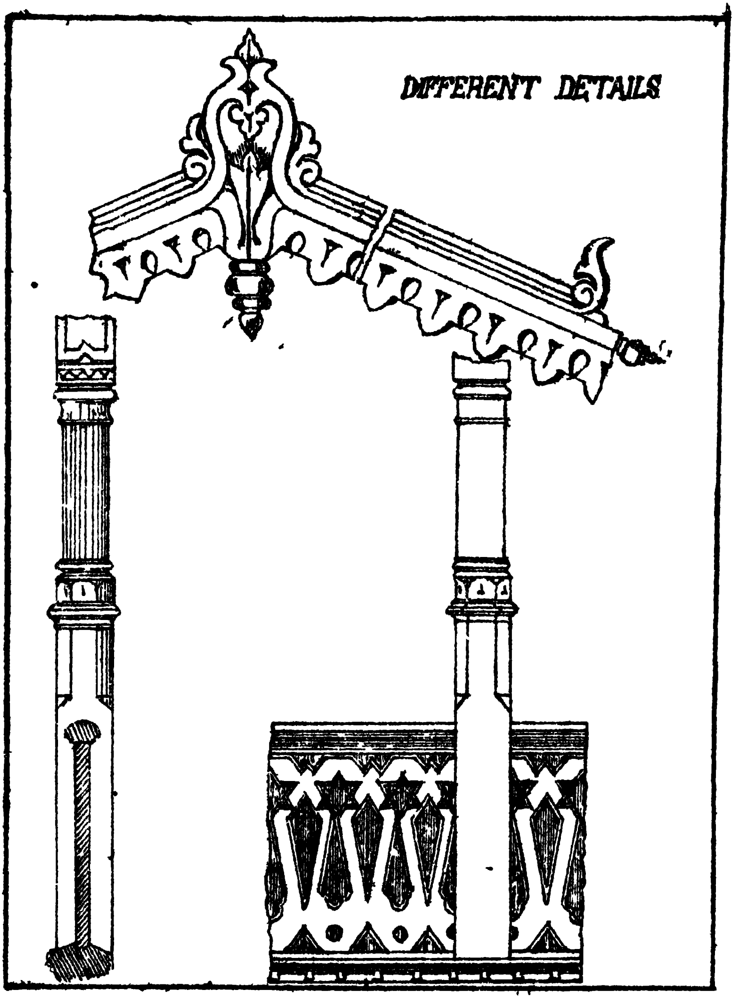

RAILINGS

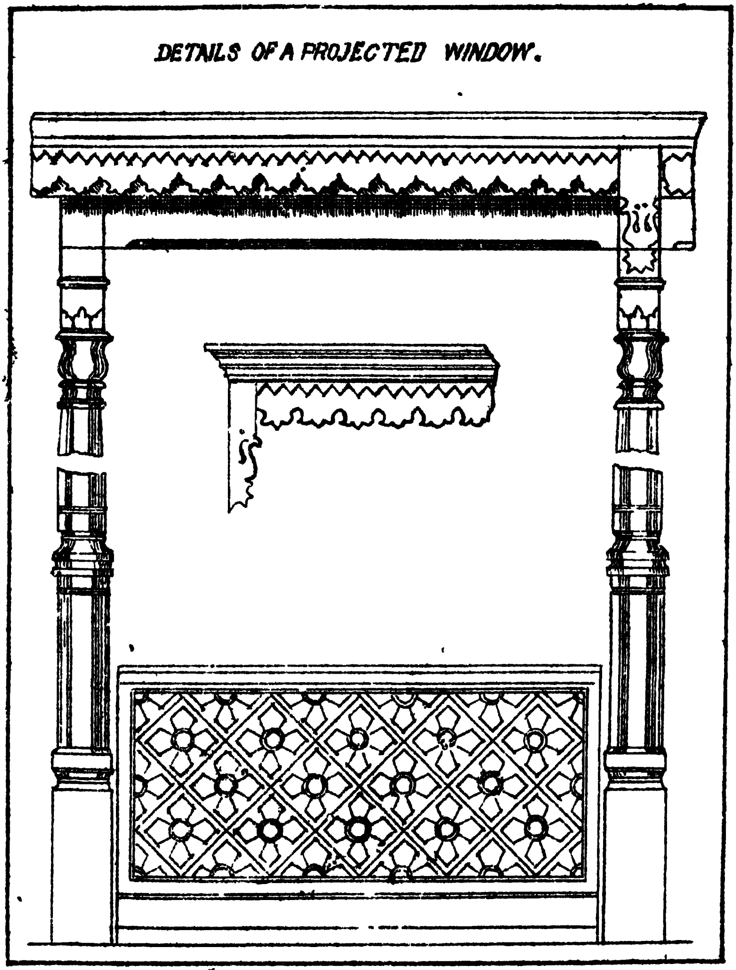


DETAILS OF GABLE FINIAL AND EAVES BOARD, Etc.

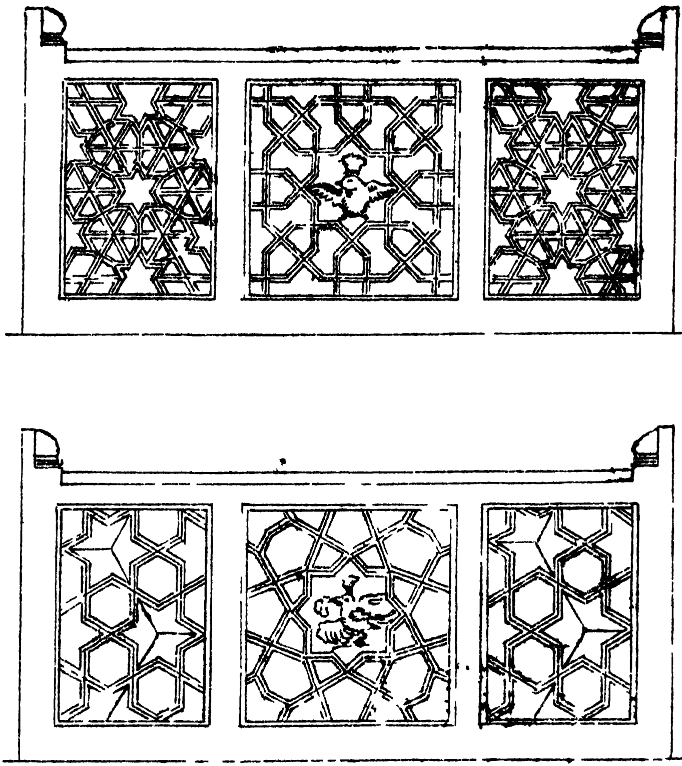

SCELLANEOUS DETAILS


DIFFERENT DETAILS

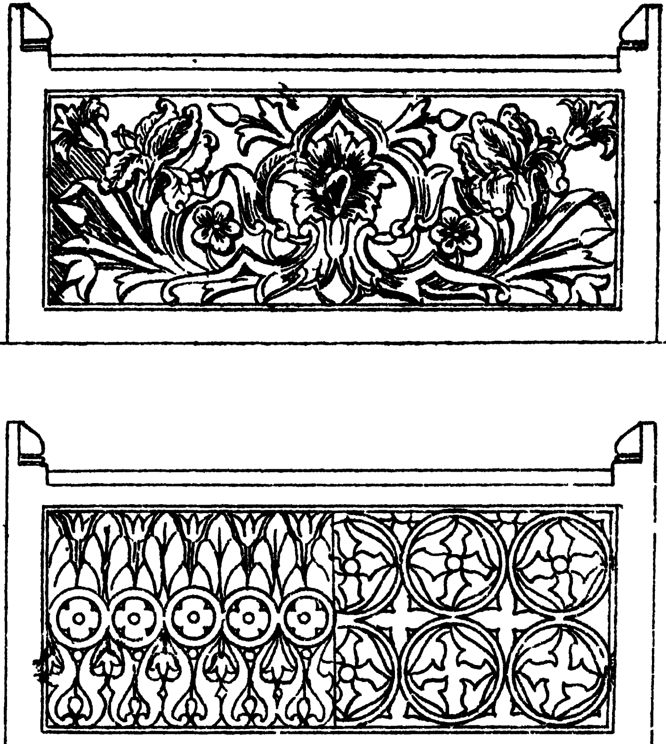

DIFFERENT DETAILS


DETAILS OF A PROJECTED WINDOW.

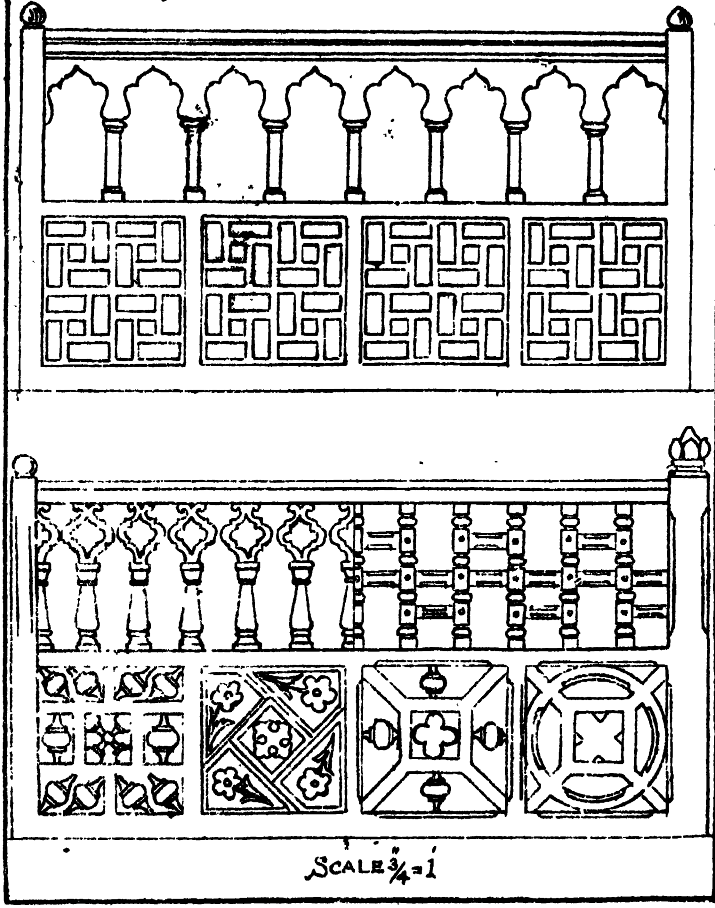
WOODEN RAILINGS.
PINJRAS.



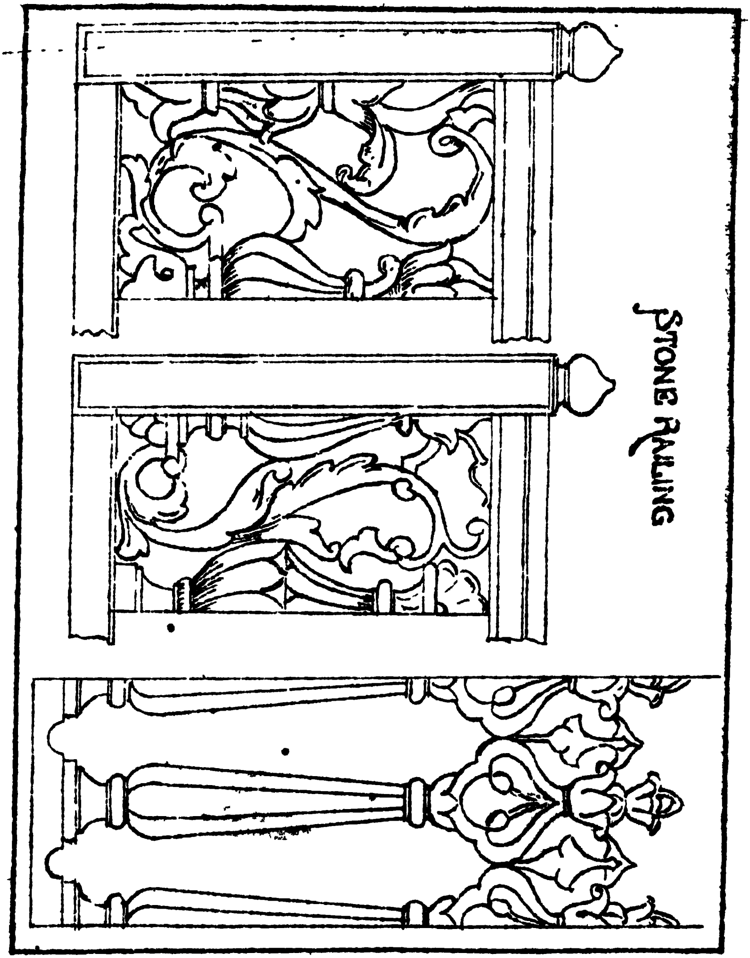
WOODEN RAILING (KATEHRA)



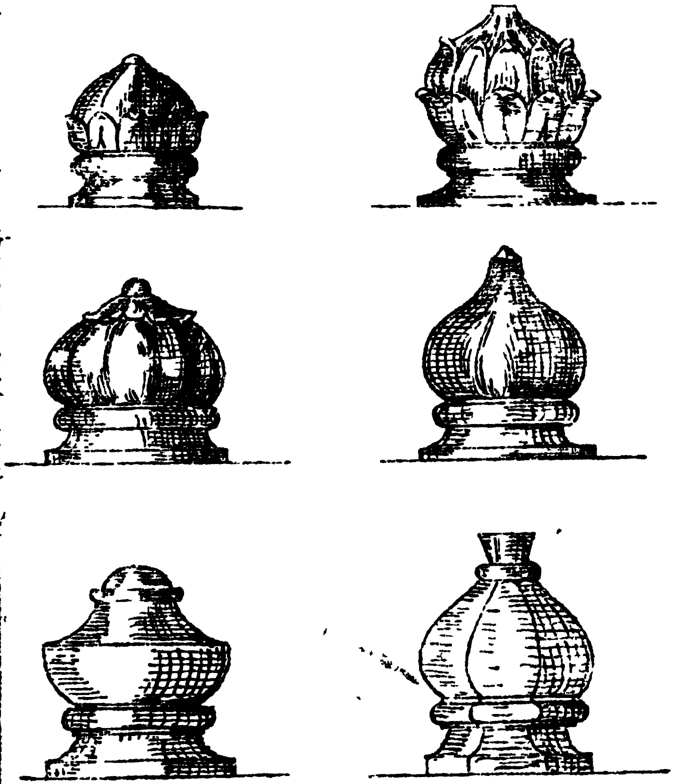
STONE & WOODEN RAILING.

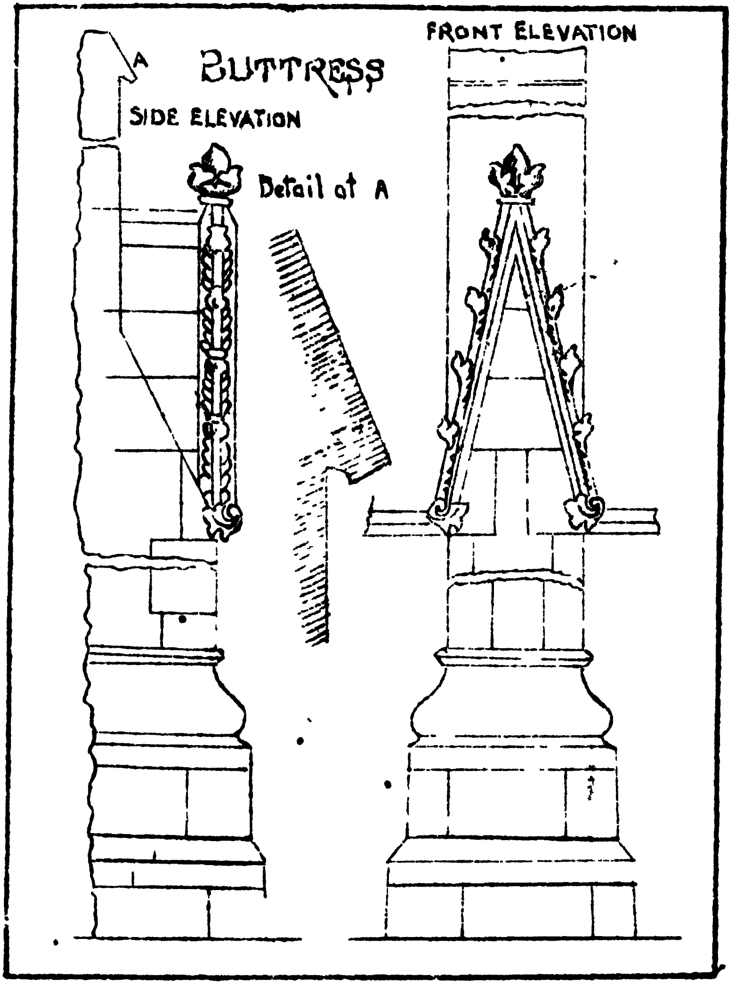


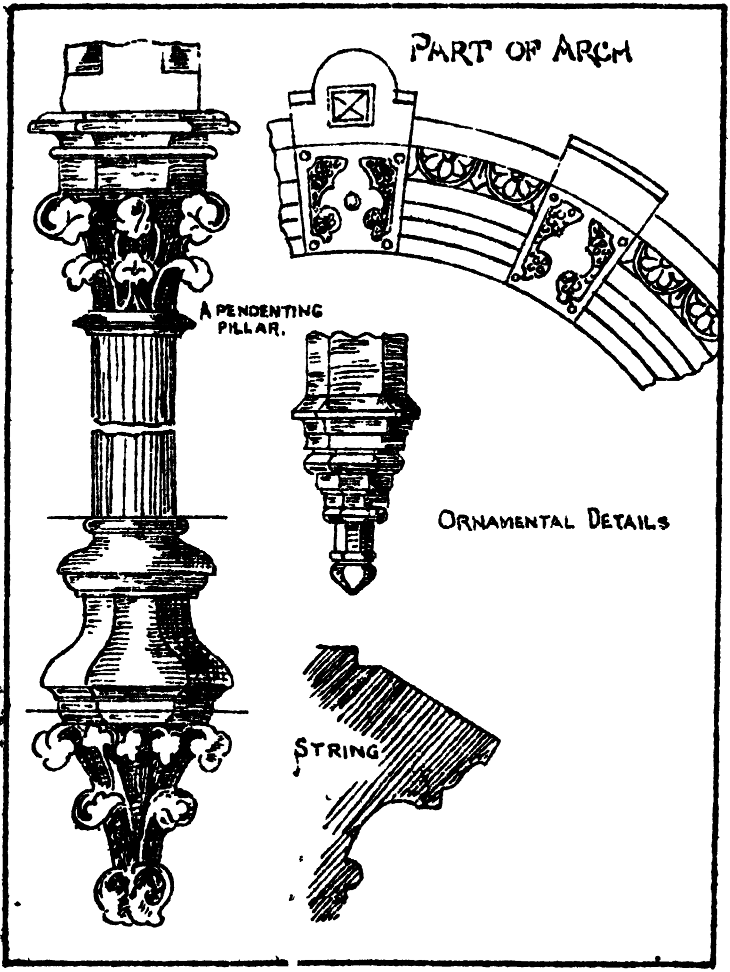
SCALE 3/4" = 1'

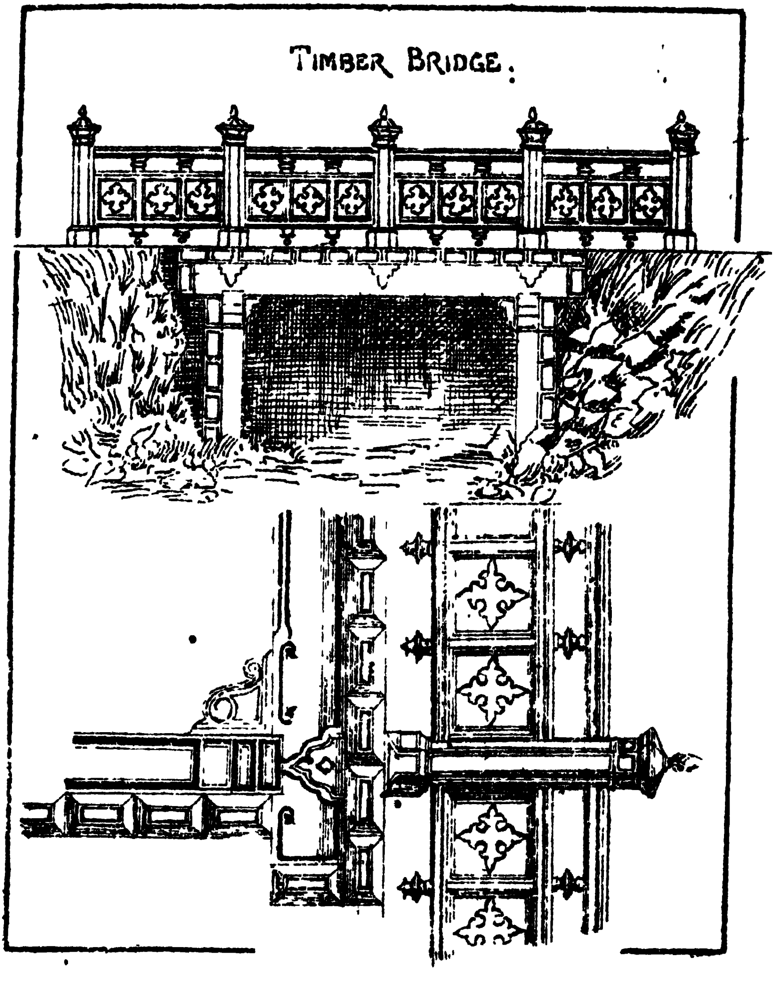

STONE RAILING

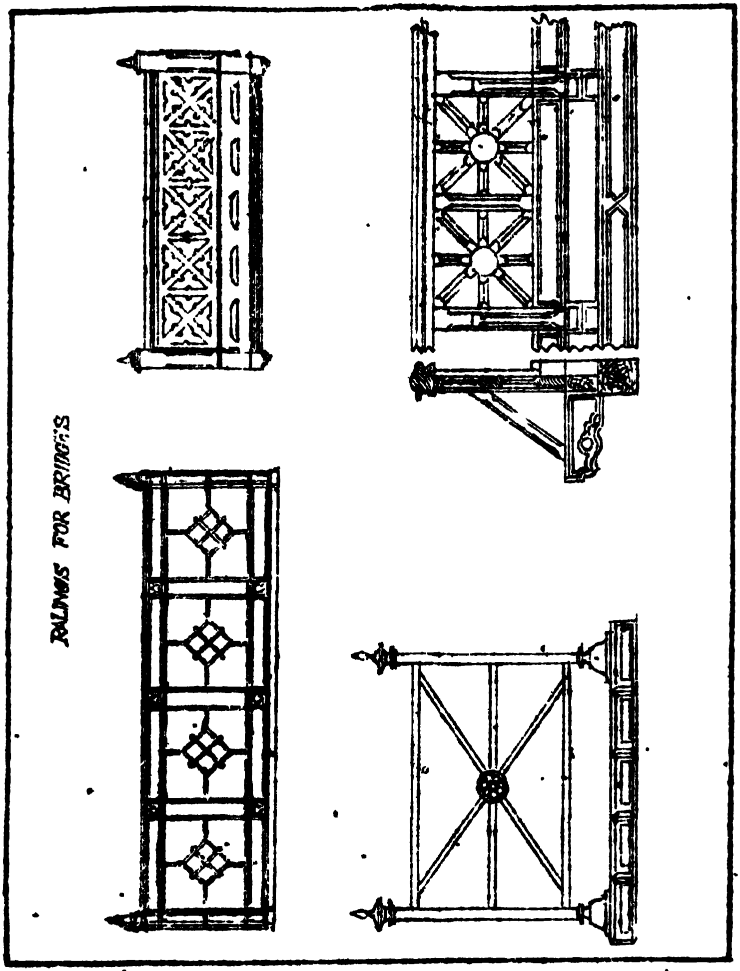
TOPS OF RAIL POSTS.



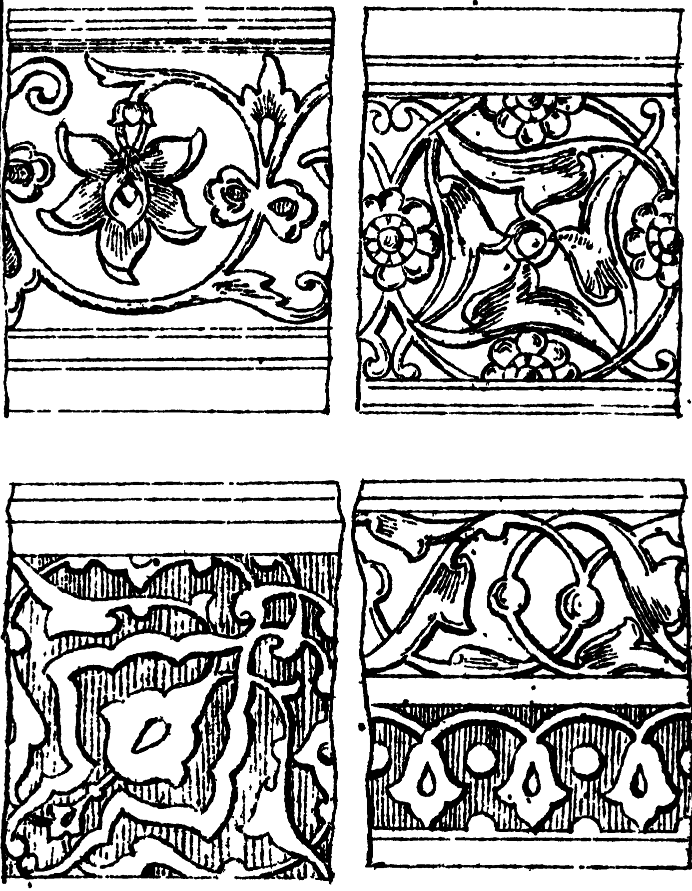

BUTTRESS
SIDE ELEVATION
A
Detail at A
FRONT ELEVATION


PART OF ARCH
A PENDENTING PILLAR.
ORNAMENTAL DETAILS
STRING

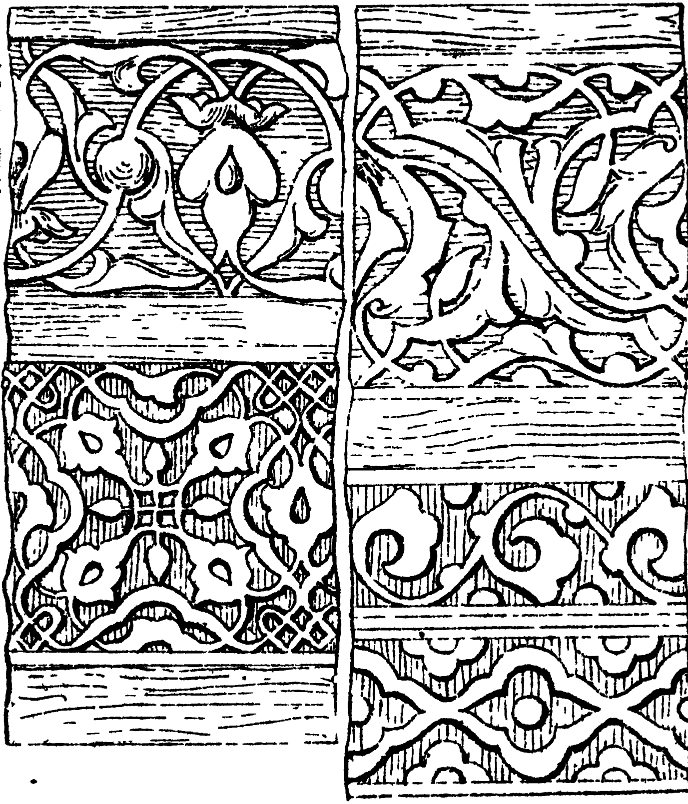

TIMBER BRIDGE.


RAILINGS FOR BRIDGES

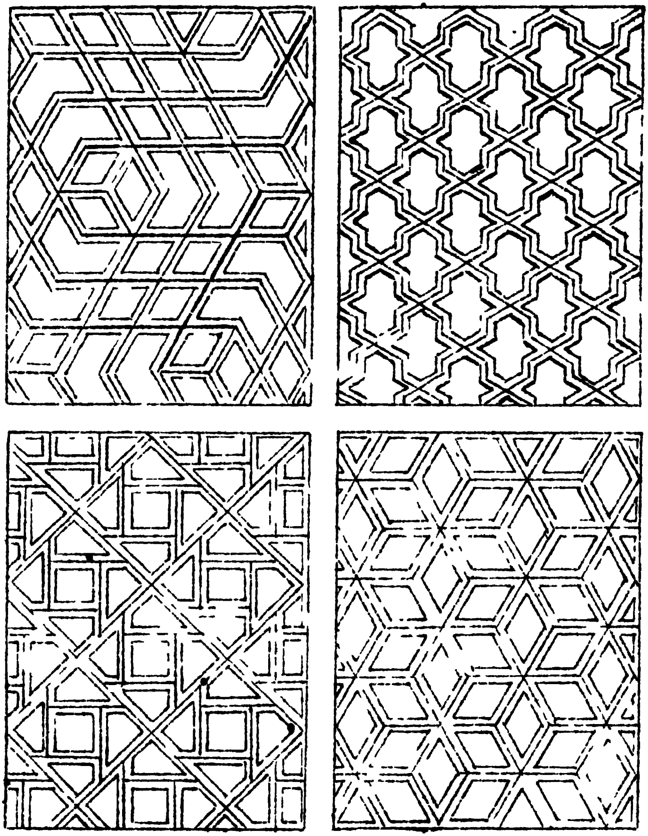
STONE CARVING



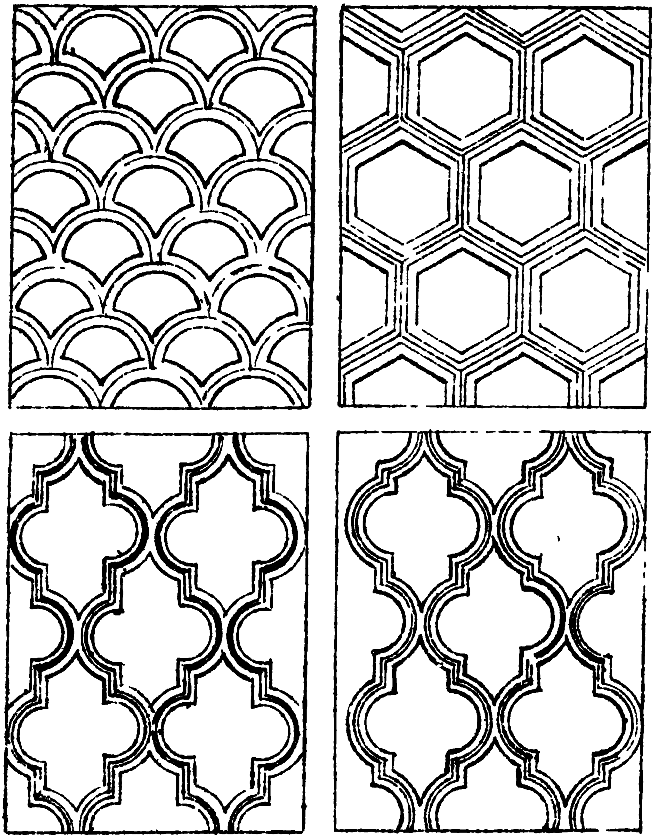
STONE CARVING.



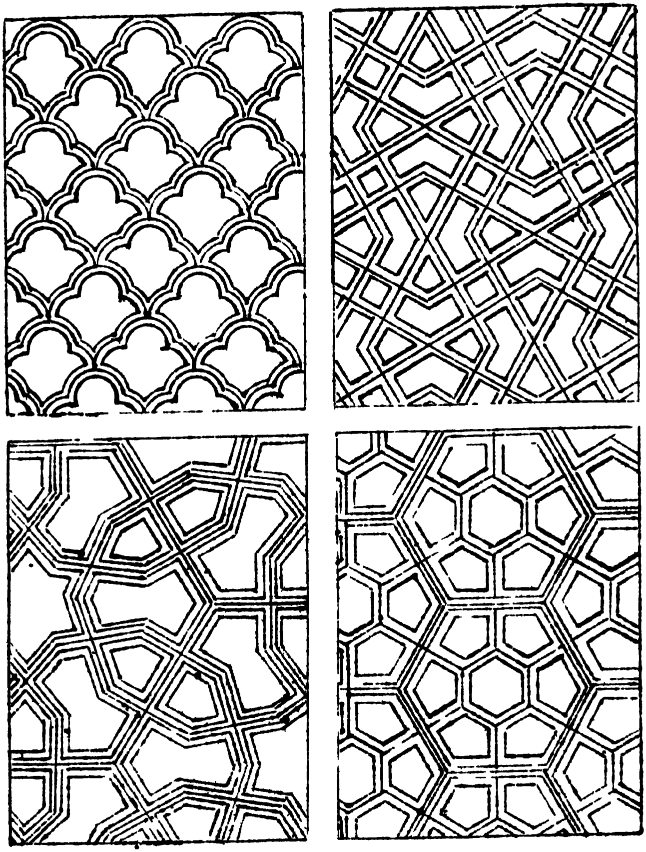
OPEN TRELLIS WORKS



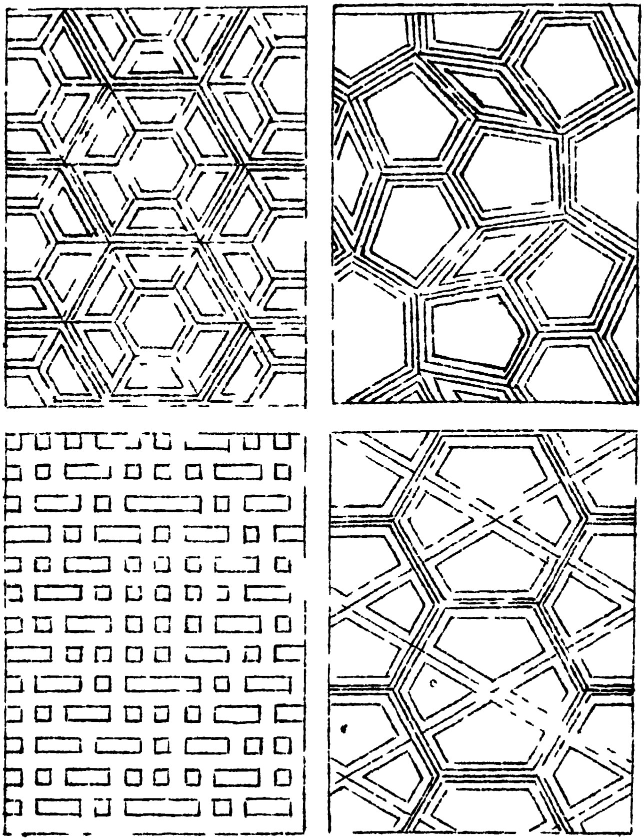
OPEN TRELLIS WORK.



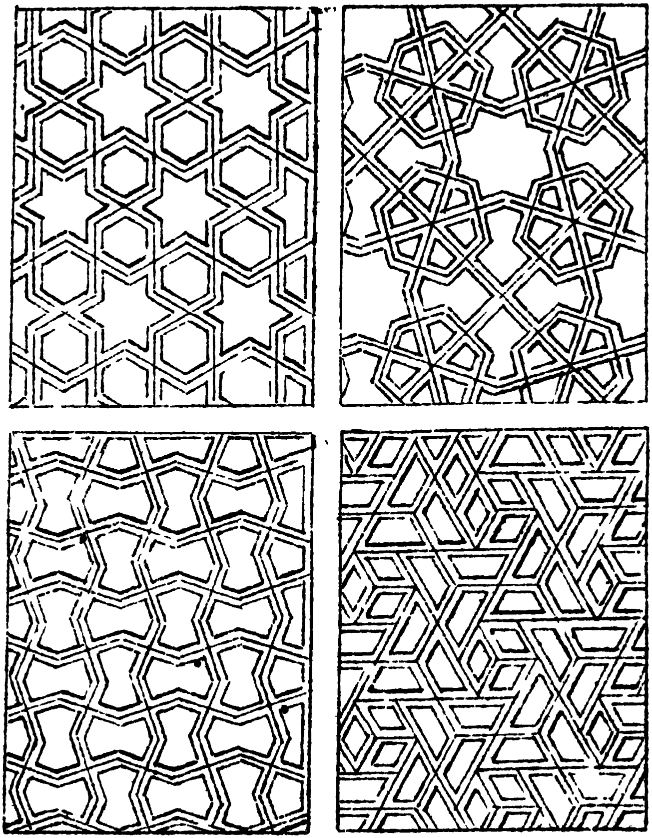
OPEN TRELLIS WORK.



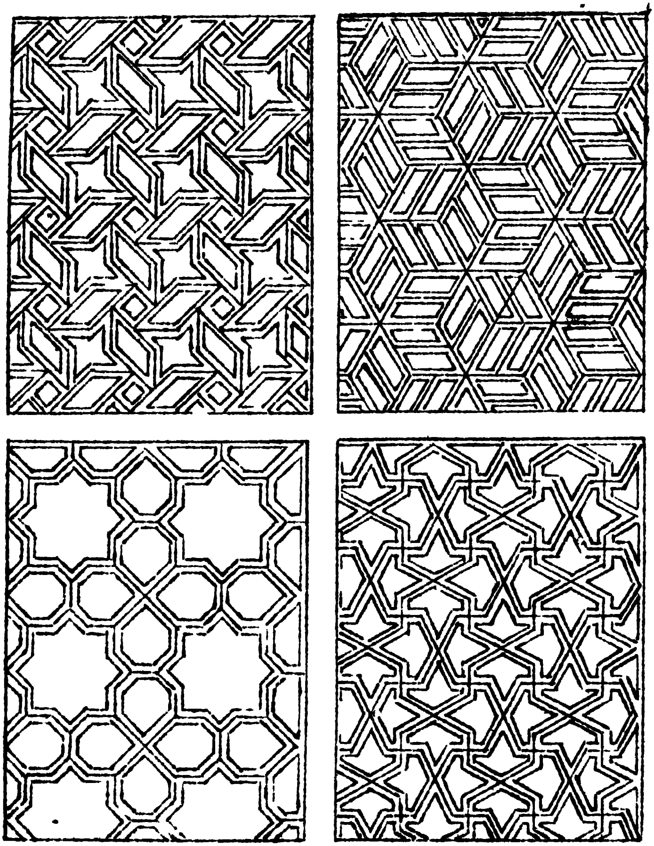
Open Trellis Works.



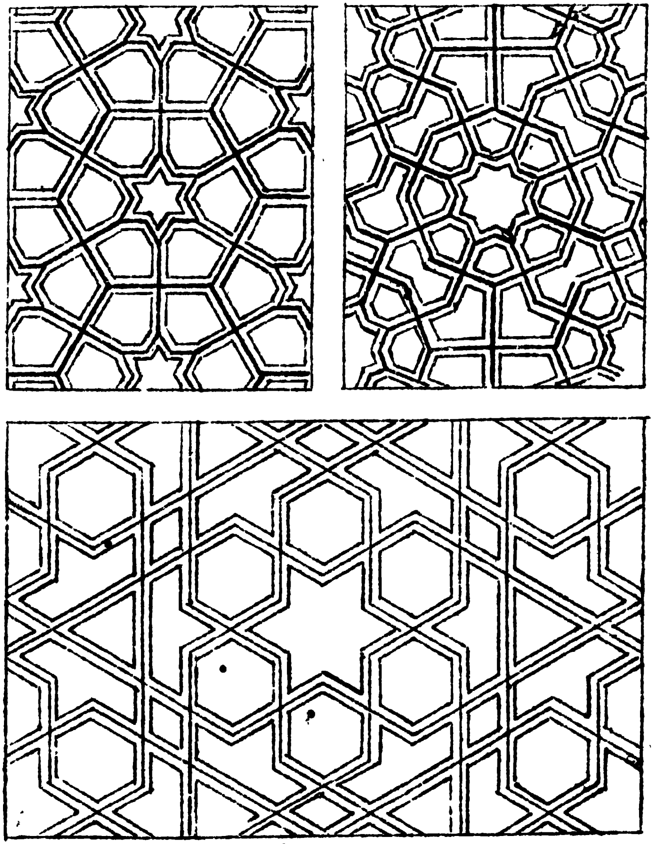
OPEN TRELLIS WORKS.



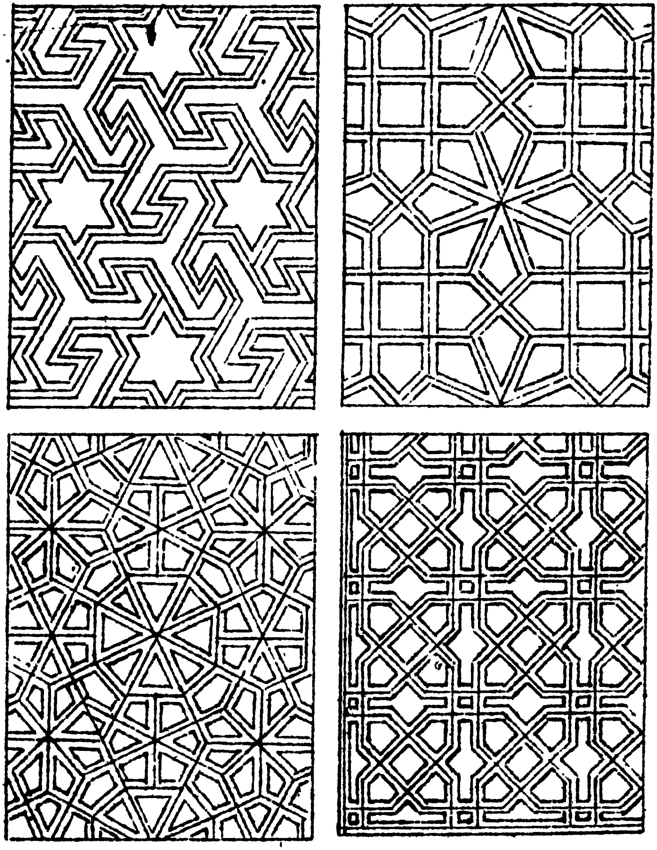
OPEN TRELLIS WORKS



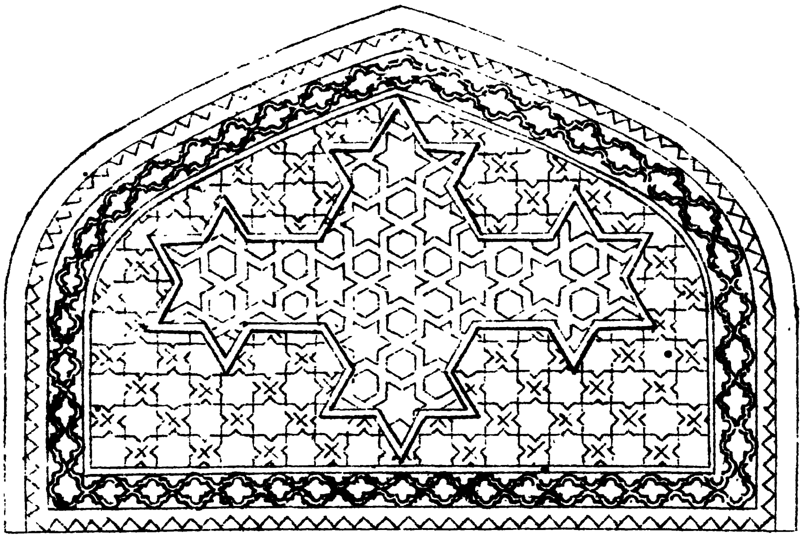
OPEN TRELLIS WORK.



Open Trellis Work

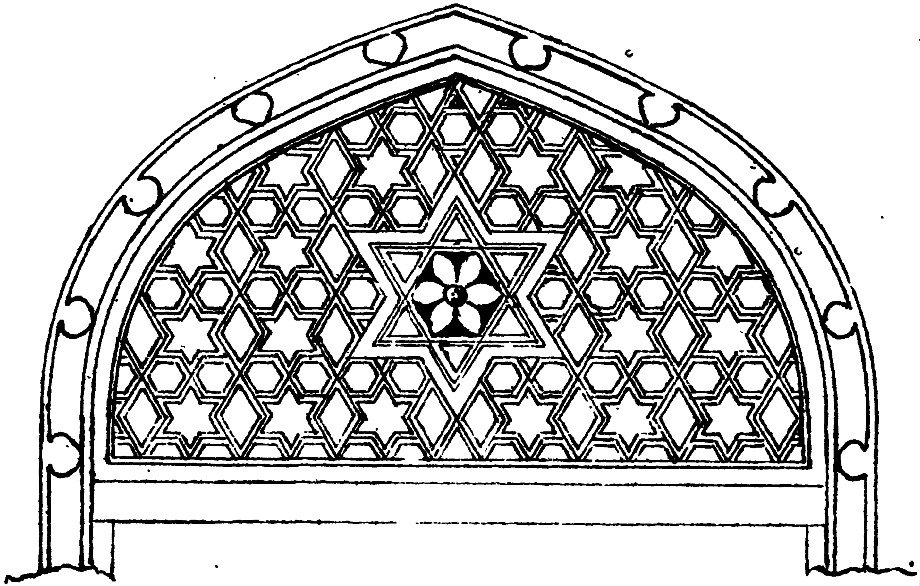


OPENINGS FILLED WITH OPEN TRELLIS WORK

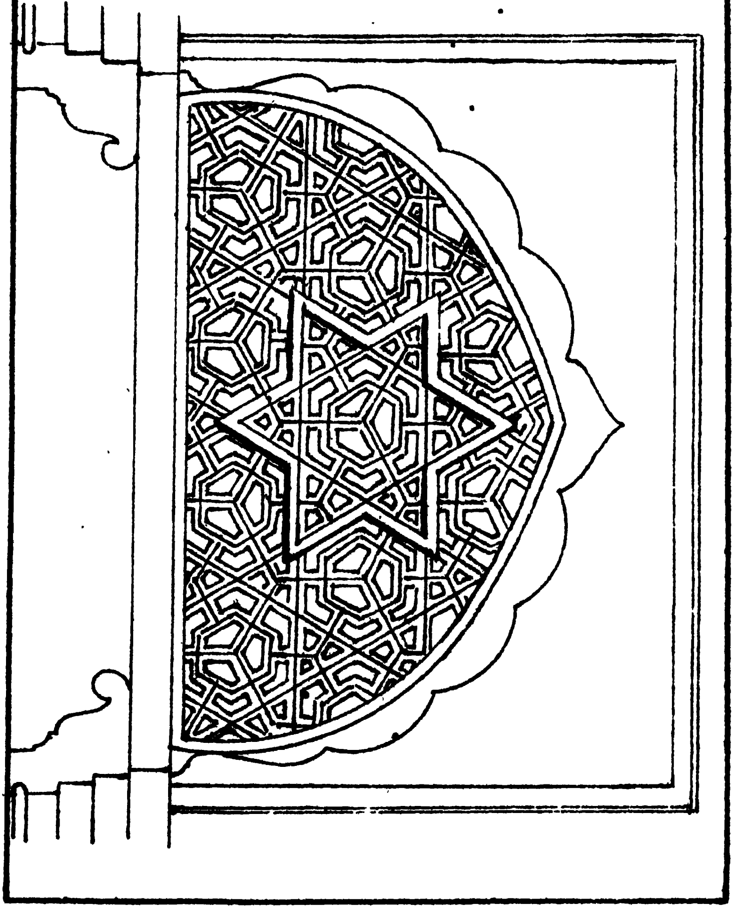


226

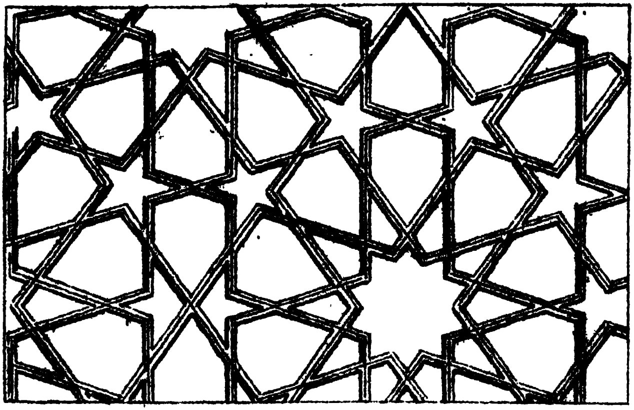
OPENING FILLED WITH OPEN TRELLIS WORK

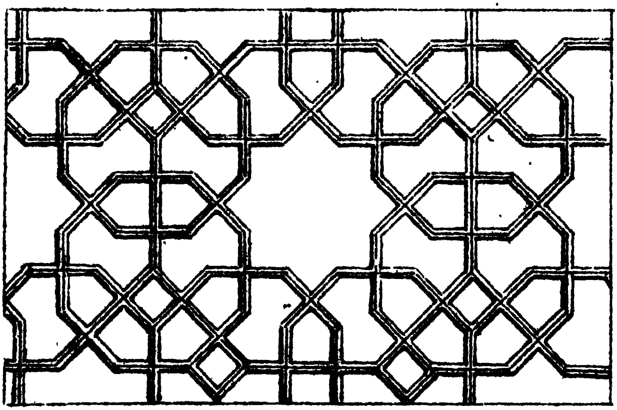


OPENING FILLED WITH OPEN TRELLIS WORKS.

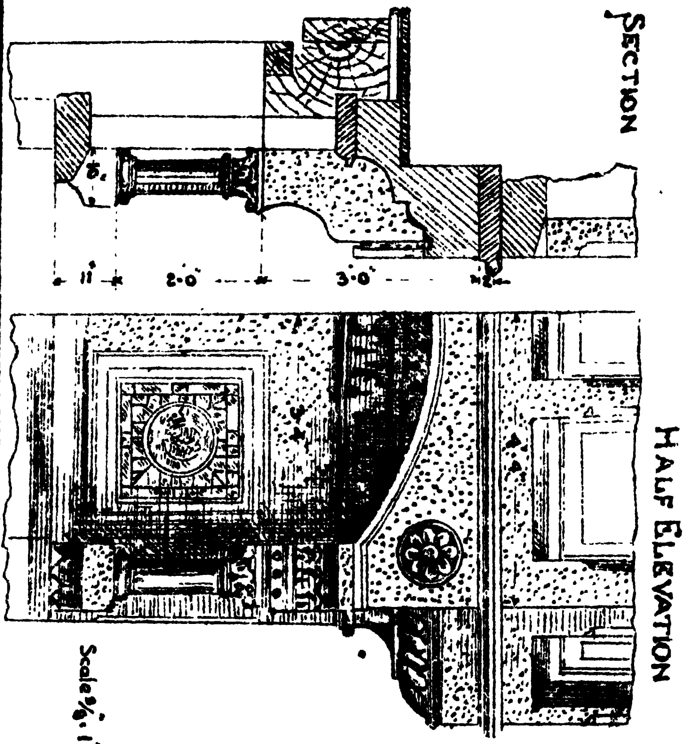


OPEN TRELLIS WORK.

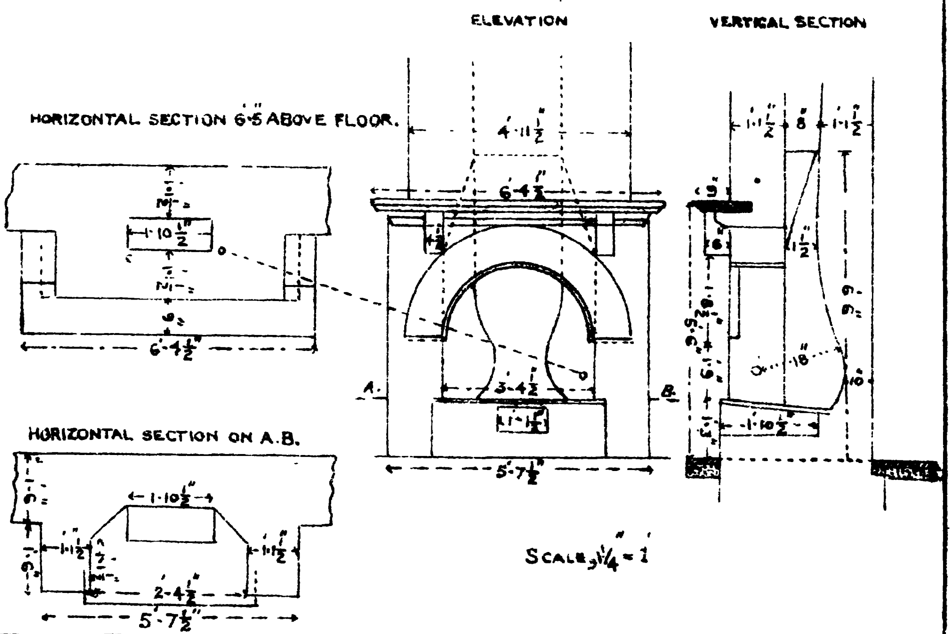


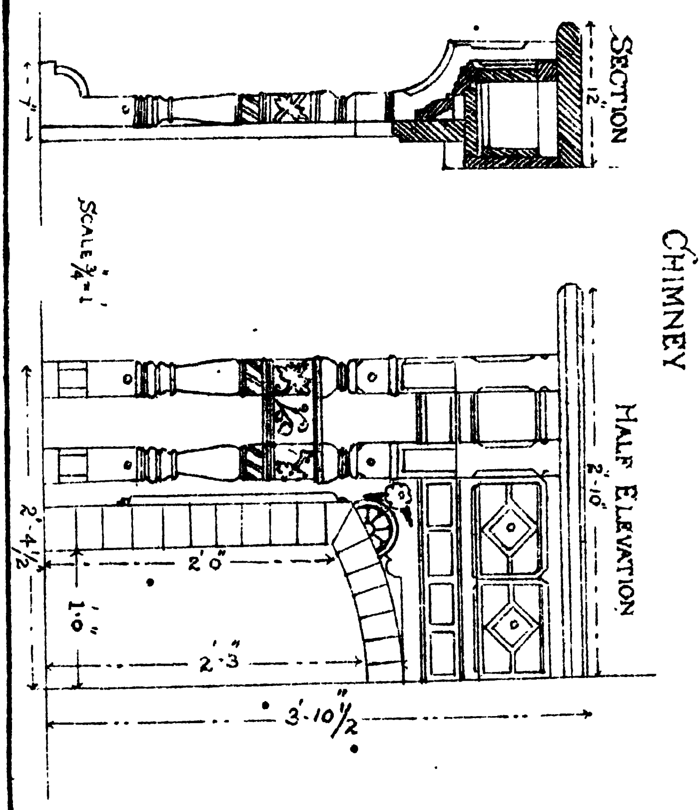


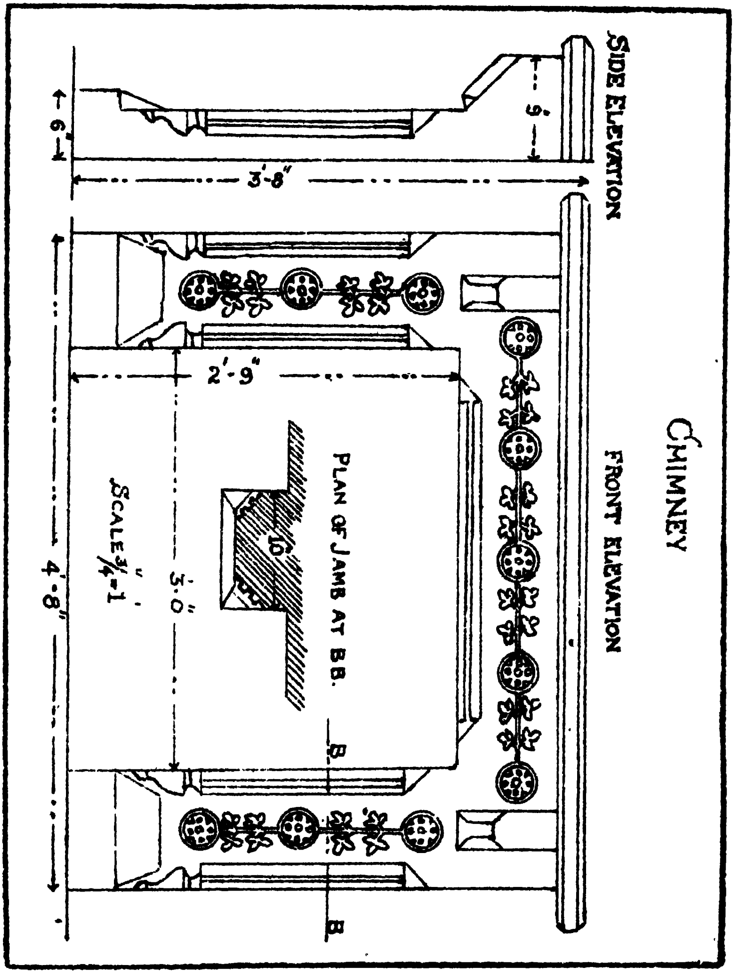
CHIMNEY PIECE



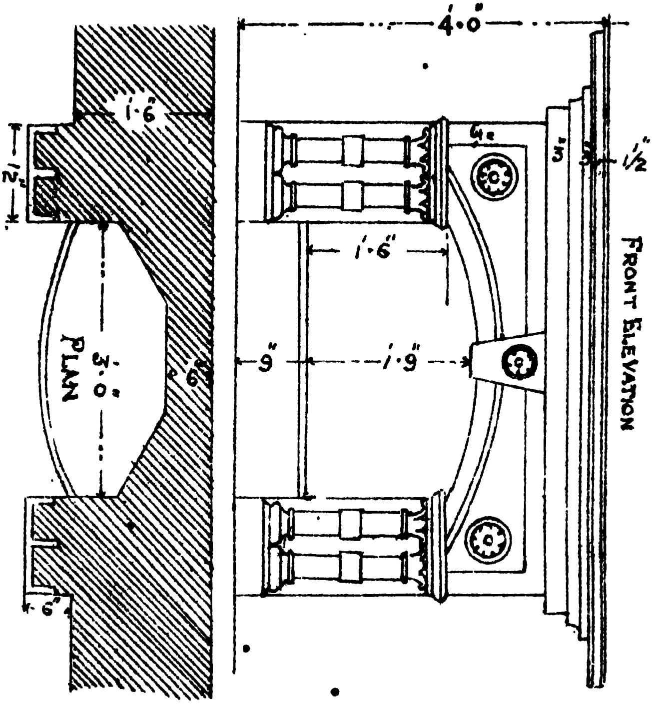
DETAIL OF A CHIMNEY.



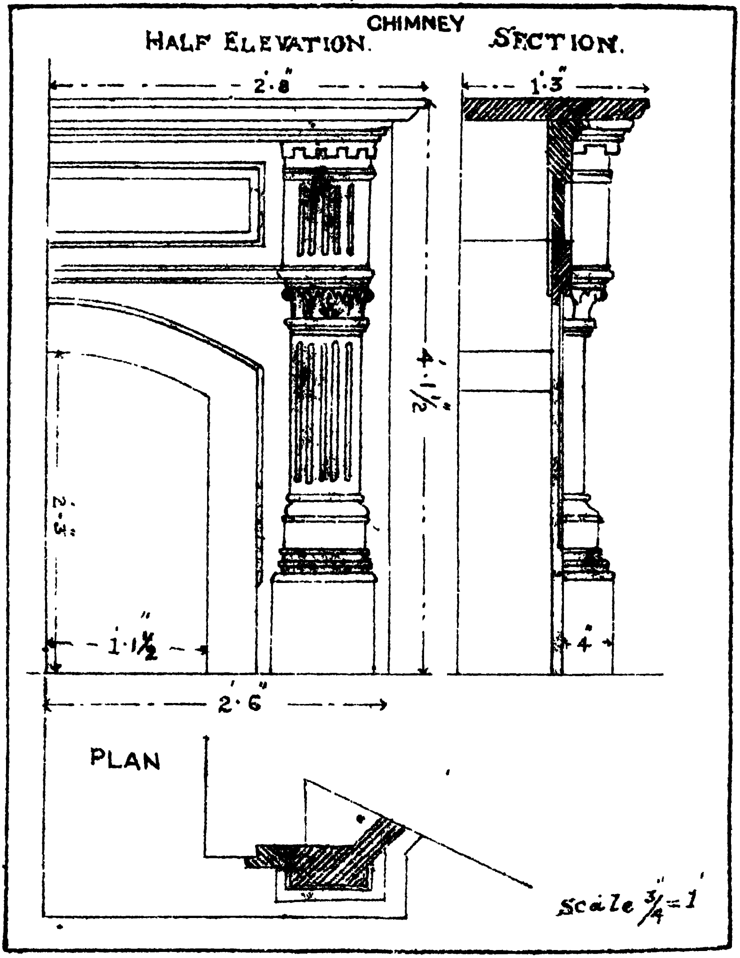

SECTION
12"
7"
CHIMNEY
HALF ELEVATION
SCALE 3/4"=1'
2'10"
2'4½"
2'0"
1'0"
2'3"
3'10½"

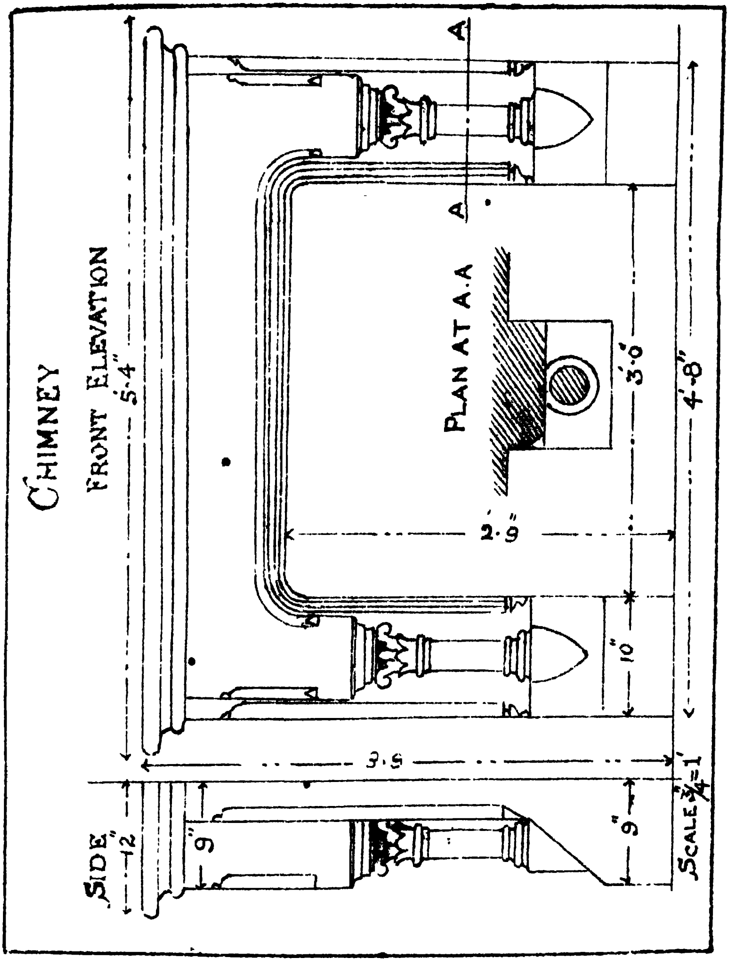

CHIMNEY
SIDE ELEVATION
FRONT ELEVATION
PLAN OF JAMB AT BB.
SCALE 3/4" = 1'
3'-8"
2'-9"
3'-0"
4'-8"
6"
9"
10"
B
B

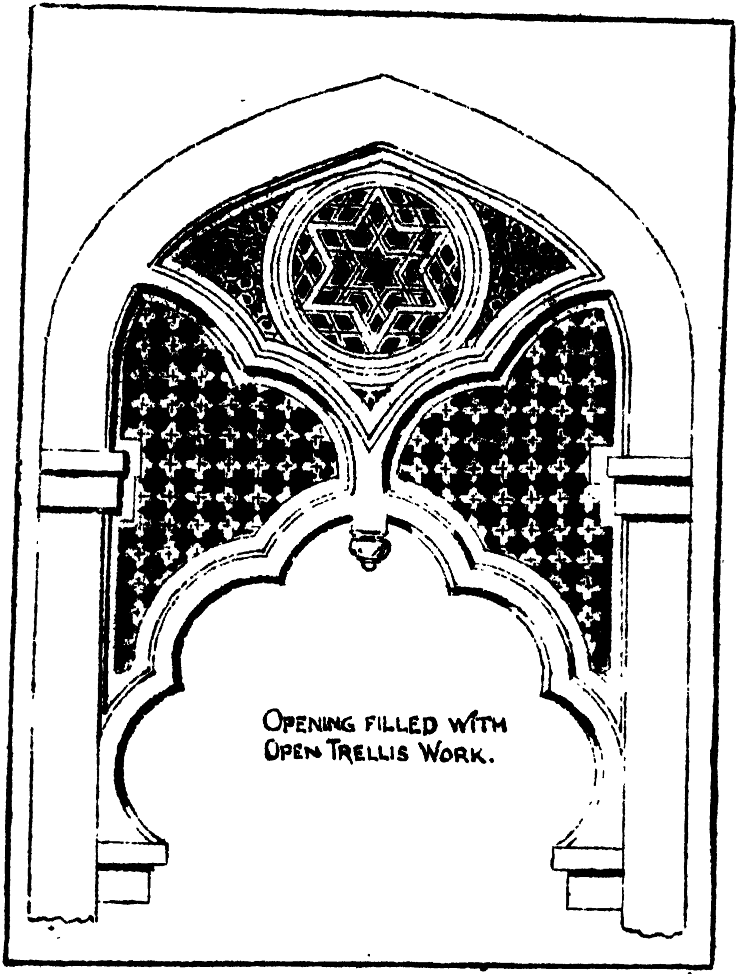
CHIMNEY

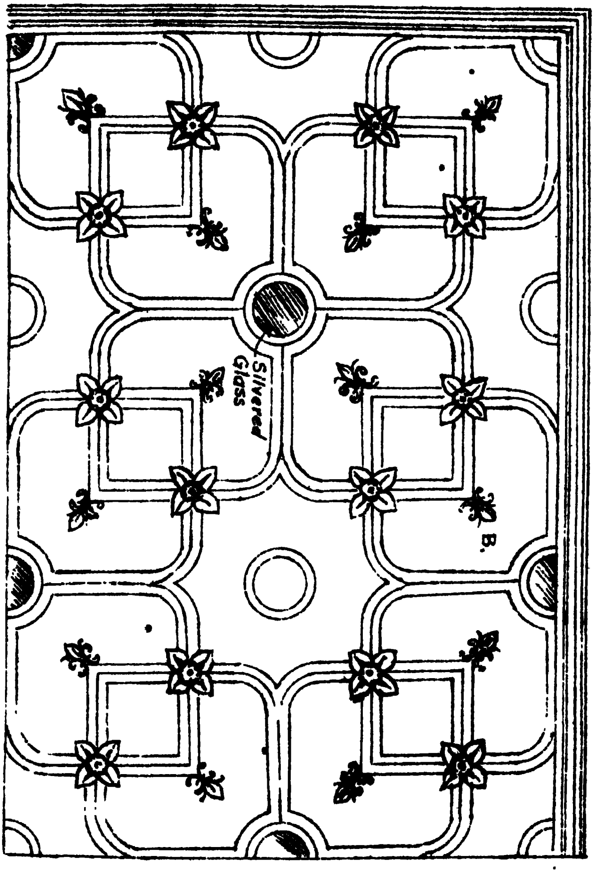


SCALE 2' = 1"

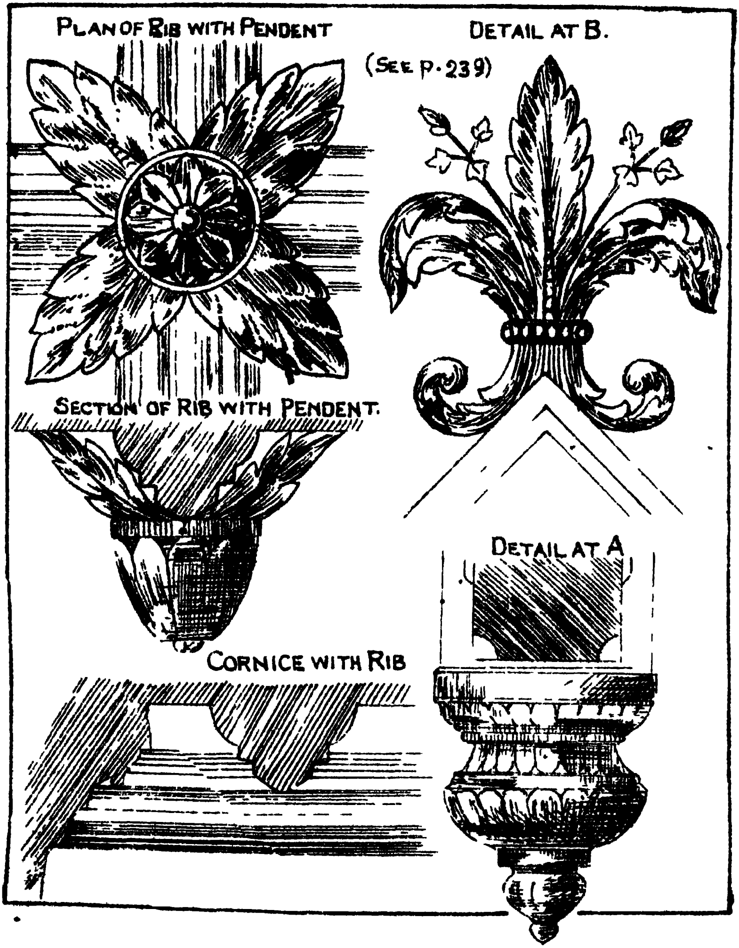

CHIMNEY
HALF ELEVATION.
SECTION.
2·8"
1·3"
4·1½"
2·3"
1·1½"
4"
2·6"
PLAN
Scale ¾"=1'


CHIMNEY
FRONT ELEVATION
5'4"
PLAN AT A.A
A
A
3'0"
4'8"
2'9"
10"
3'9
SIDE
12"
9"
9"
SCALE 3/4"=1'


OPENING FILLED WITH
OPEN TRELLIS WORK.



DESIGN FOR CEILING.


PLAN OF RIB WITH PENDENT
DETAIL AT B.
(SEE P. 239)
SECTION OF RIB WITH PENDENT.
DETAIL AT A
CORNICE WITH RIB

REINFORCED BRICK-WORK & R. CONCRETE.

Proportion of cement mortar-cem-1: sand 2½ or 3 (vol.) proportion of cement-concrete-cement-1-8 and 2½ or 3 stone chips or picked jhama chips 3½ or 4 for slabs of big spans or with heavy loads the proportion is 1:2:3 gauge of chips ¼" to ½" cem-mortar tiles are made by cutting ½" cement plaster 2 or 2½ : 1 on any sandy surface.

All bottom tension rods-embedded in cem-concrete. Top rods and cross rods-embedded in cem-concrete or mortar.

Method of construction-lay bricks in cement mortar with tiles in longitudinal joints (and cross joints where necessary.) Spread reinforcing rods over those tiles at the centre of joints. ¾" above centering. This is done by using tiles with upwards projections (⊥) or by using cross rods in mortar or concrete joints below the main tension rods Put ¾" mortar first and then pour concrete of wet consistency in joints. Lay upper courses of Brickworks in cement mortar where necessary.

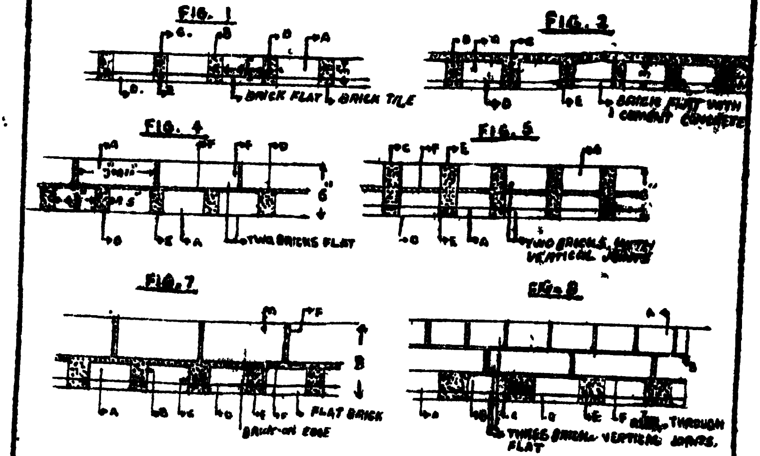
Note —Reinforcing rods, being embedded in wide ribs of cement concrete have ample cover of concrete on all sides, for protection against rusting. Thus in these improved R. B. & R B. C. Slabs there is no fear of rusting of rods.

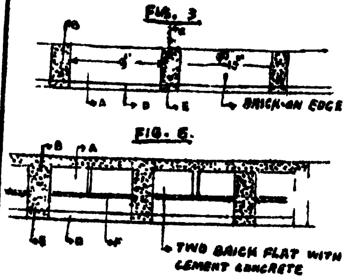
In wide ribs of cement concrete several rods can be used in one joint, Slabs with cement concrete at top (as Figs 2, 6) are equally stiff and strong as reinforced concrete slabs and stiffer and stronger than R, B, Slabs. The depths of slabs are increased by adding ½" cement plaster or 1" to 1½" cement concrete along with the construction of slabs. The depths of slabs should not be less than $\frac{1}{30}$th of span in ordinary cases.

IMPROVED REINFORCED BRICK WORK SLABS.

DATTA'S SYSTM
PATENTED

CROSS SECTIONS FOR R.B. SLABS (IMPROVED)

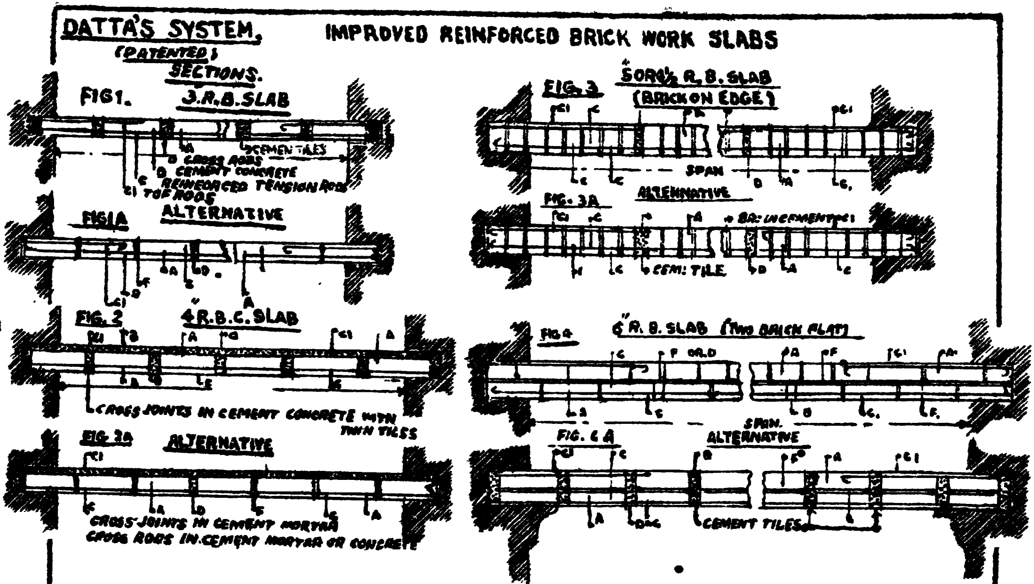




REFFRENCES.

Ref.	Details.
A	Bricks or brick work (Cem.)
B	Cement concrete.
C	Reinforcing tension rods.
D	Cross rods.
E	Thin tiles of mortar or of Burnt clay.
F	Cement mortar.

Tiles are made ¼″ thick, 1½″ to 3″ wide, 4½″ to 7½″ in length, tne tiles being laid between bricks or brick work cover the ordinary centering bellow and from shuttering for the contrete above ; they help substantially in proper positioning of reinforcement.



REFERENCES.

A.	Brick or Brick work in cement	D	Cross rods
B.	Cement concrete	E.	Thin tiles of mortar (cement) or of burnt clay (usually ¼" thick)
C.	Reinforcing tension rods	F.	Cement morter
C1.	Top reinforcing rods		

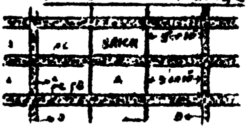
IMPROVED REINFORCED BRICK WORK SLABS

PLANS

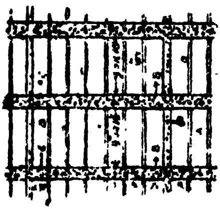
PLANS OF FIGS 1,2 & 4A



PLANS OF FIGS 1A 2.A & 4



PLANS OF FIGS. 3 & 3A

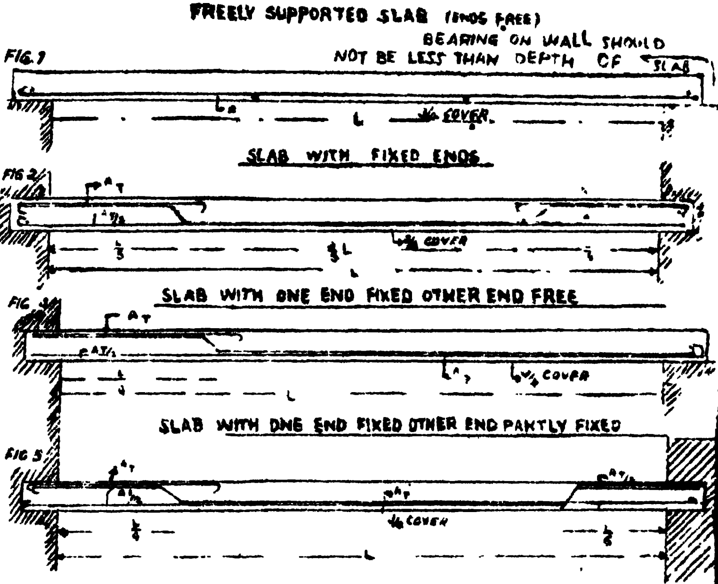


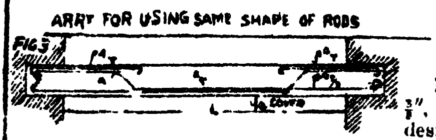
For ordinary roofs and floors.

Safe super imposed load in tons per sq. ft.

ON SLABS		Max Spans recommended.		
		For slabs with ends partly fixed Reinforced one way (for $m = \frac{WL^2}{10}$)		
Depth of Slab.	Effective depth	R. B.	R. C. C.	Remarks.
3"	2¼"	6'	7'	For slabs reinforced in one way fixed or continous, should have depth not less than $\frac{1}{30}$th of span in ordinary cases (Superimposed load-weight of surfaceing material and live load).
3½"	2¾"	7'	8'	
4"	3¼"	8'	10'	
4½"	3¾"	9'	11'	
5"	4"	10'	12'	
5½"	4½"	11'	13'	
6"	5"	12'	14'	
6½"	5½"	13'	15'	
7"	6"	14'	16'	R. B. C. slabs are reinforced brickwork slabs with cement concrete on top as in Fig 2.
8"	6¾"	15'	18'	
9"	7¾"	16'	19'	
10"	8¾"	18'	21'	
12"	10½"	20'	24'	
14"	12½"	22'	27'	
16"	14½"	24'	30'	

DIAGRAMS FOR POSITIONS OF REINFORCEMENTS IN SLABS



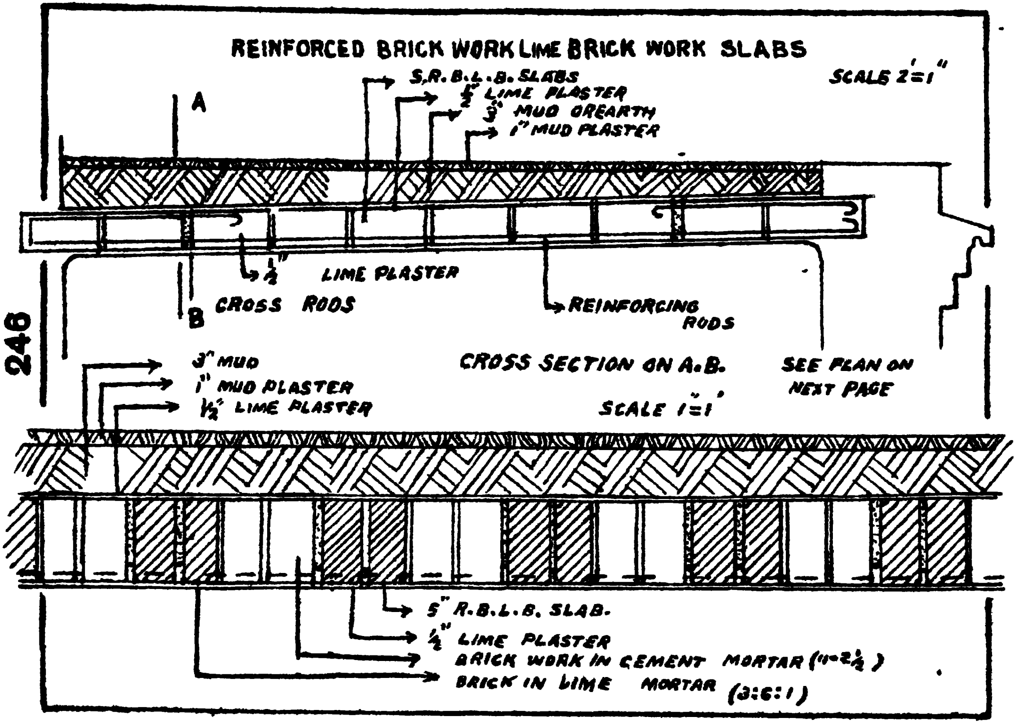


NOTES—1. Cross rods $\frac{5}{16}''$ or $\frac{3}{8}''$, 30″ apart or as directed by designer should be used.

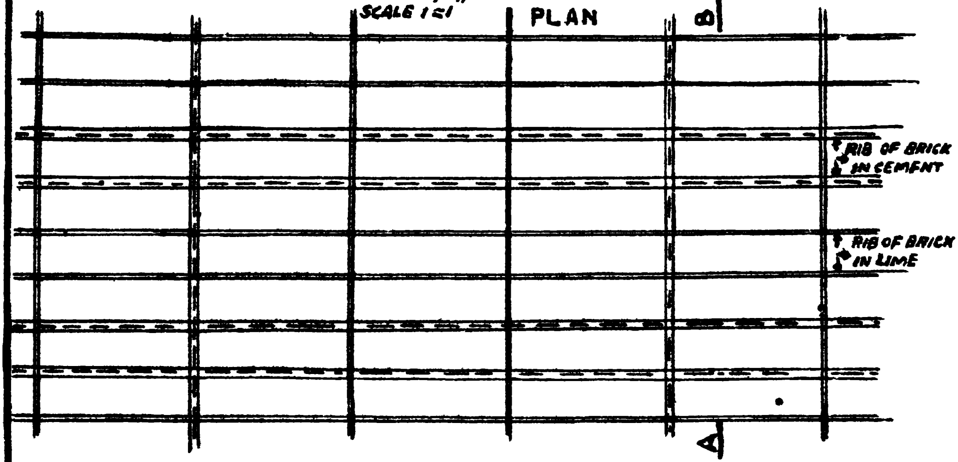
2. Cover of mortar or concrete on rods from under-side $\frac{3}{4}''$

3. Cover between rods and side brick, $\frac{3}{8}''$

4. All rods should be cleared of dust and coated with 2 coats of cement wash before use.


REINFORCED BRICK WORK LIME BRICK WORK SLABS
SCALE 2'=1"
S.R.B.L.B. SLABS
½" LIME PLASTER
3" MUD OR EARTH
1" MUD PLASTER
A
B
½" LIME PLASTER
CROSS RODS
REINFORCING RODS
CROSS SECTION ON A.B.
SEE PLAN ON NEXT PAGE
SCALE 1"=1'
3" MUD
1" MUD PLASTER
½" LIME PLASTER
5" R.B.L.B. SLAB.
½" LIME PLASTER
BRICK WORK IN CEMENT MORTAR (1:2½)
BRICK IN LIME MORTAR (3:6:1)

REINFORCED BRICK WORK · LIME BRICK WORK SALBS.



REINFORCING STEEL RODS LENGTHWISE & CROSSWISE ARE EMBEDDED IN CEMENT MORTAR JOINTS. REMAINING JOINTS ARE IN LIME MORTAR

CEMENT MORTAR
- CEMENT — 1
- SAND — 2½

LIME MORTAR
- WHITE LIME 3
- SOORNEE 6
- CEMENT 1

CROSS SECTIONS OF REINFORCED BRICK WORK LIME CONCRETE & REINFORCED BRICK WORK LIME BRICK WORK SLABS.

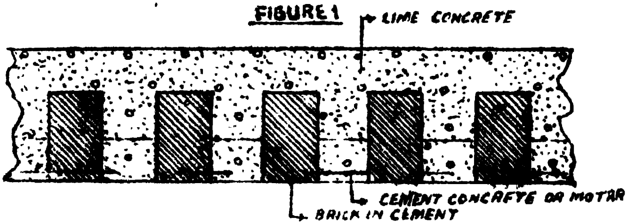


FIGURE 1

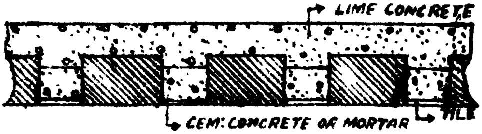


FIGURE 2

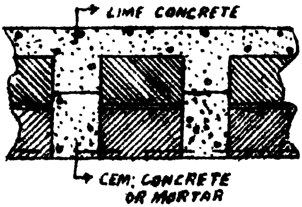


FIGURE 3

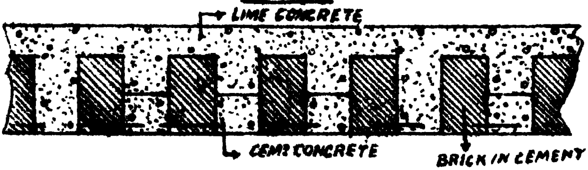


FIGURE 4

CROSS SECTIONS OF REINFORCED BRICK WORK LIME CONCR-ETE & REINFORCED BRICK WORK LIME BRICK WORK SLABS.

FIGURE 5

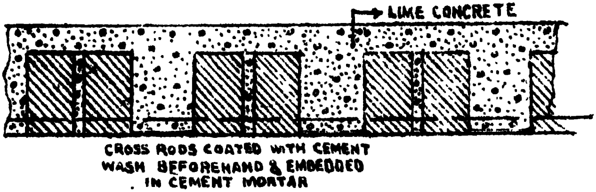


FIGURE 6

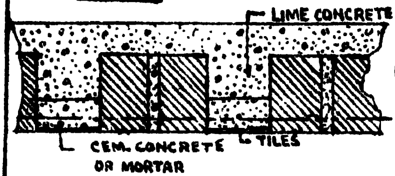


FIGURE 7

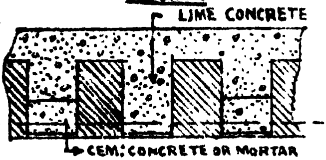


FIGURE 8

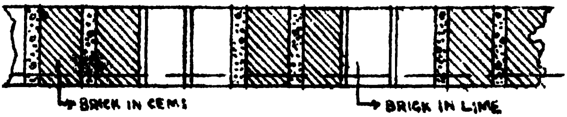
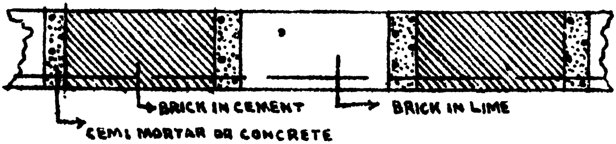


FIGURE 9



CROSS SECTIONS OF REINFORCED BRICK WORK LIME CONCRETE & REINFORCED BRICK WORK LIME BRICK WORKSLABS.

FIG. 10

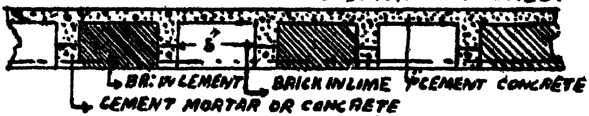


FIGURE 11

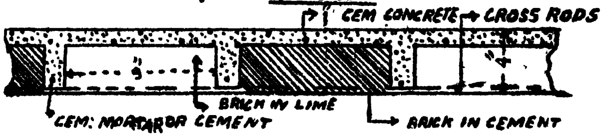
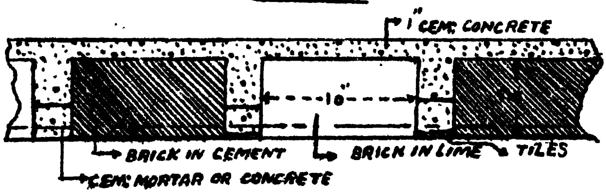


FIGURE 12



NOTES.—Rods embedded in lime mortar or lime concrete should be coated with 2 coats of cement linseed oil wash beforehand.

Brick in lime can be used in place of brick in cement where compressive stresses are taken fully by the lime concrete or cement concrete.

Thin tiles as 5" or 6"×1½"×½" may be used in joints where necessary.

Proportion of cement mortar :—cement—1, sand 2½" (by volume).

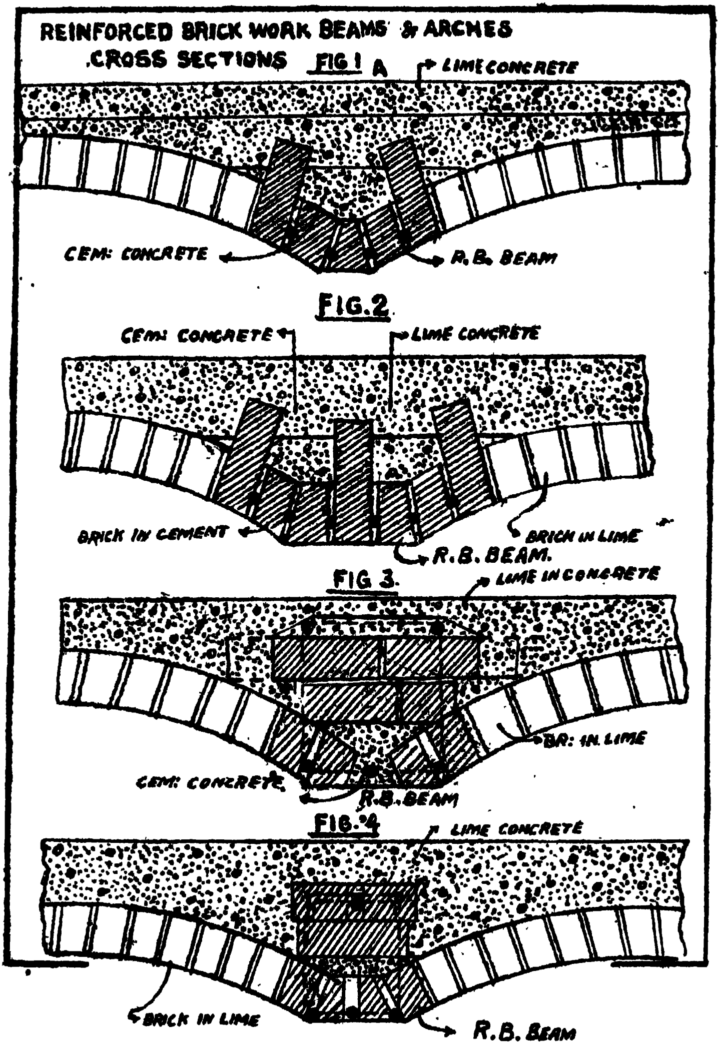
Proportion of line mortar :—slaked lime—3, soorkhi—6, cement—1, or kunkur lime—6, cem—1 (if lime is not of good quality.)

Proportion of cement concrete :—cement—1, sand—2½ ballast—3½ or 4 or cement—1, sand 2, & ballast—3

For lime concrete use 50 to 66 per cent. of lime mortar.

Gauge of brick ballast—¾" for lime concrete.

The centering for R.B.L.C. slabs should not be removed earlier than ten days.



REINFORCED BRICK WORK BEAMS & ARCHES
CROSS SECTIONS
FIG 1
A
LIME CONCRETE
CEM: CONCRETE
R.B. BEAM
FIG.2
CEM: CONCRETE
LIME CONCRETE
A
BRICK IN CEMENT
BRICK IN LIME
R.B. BEAM.
FIG 3.
LIME IN CONCRETE
BR: IN LIME
CEM: CONCRETE
R.B. BEAM
FIG.4
LIME CONCRETE
BRICK IN LIME
R.B. BEAM

REINFORCED BRICK WORK BEAM & ARCHES (CONTD)

CROSS SECTIONS

FIG. 5

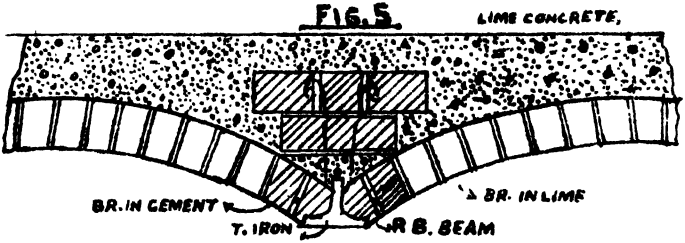


FIG. 6

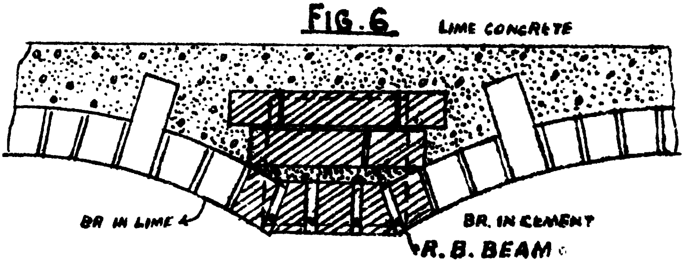
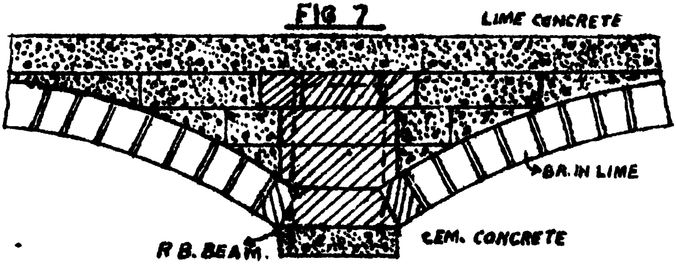
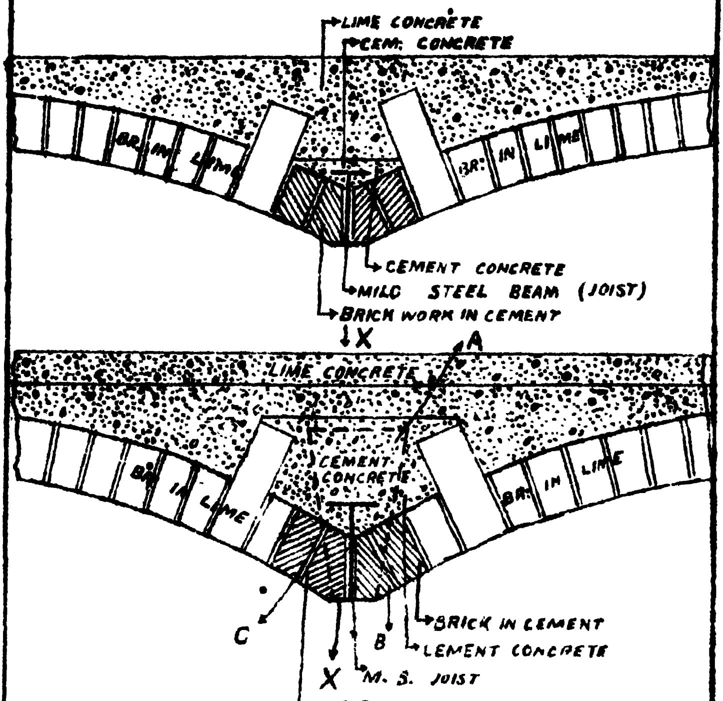


FIG 7

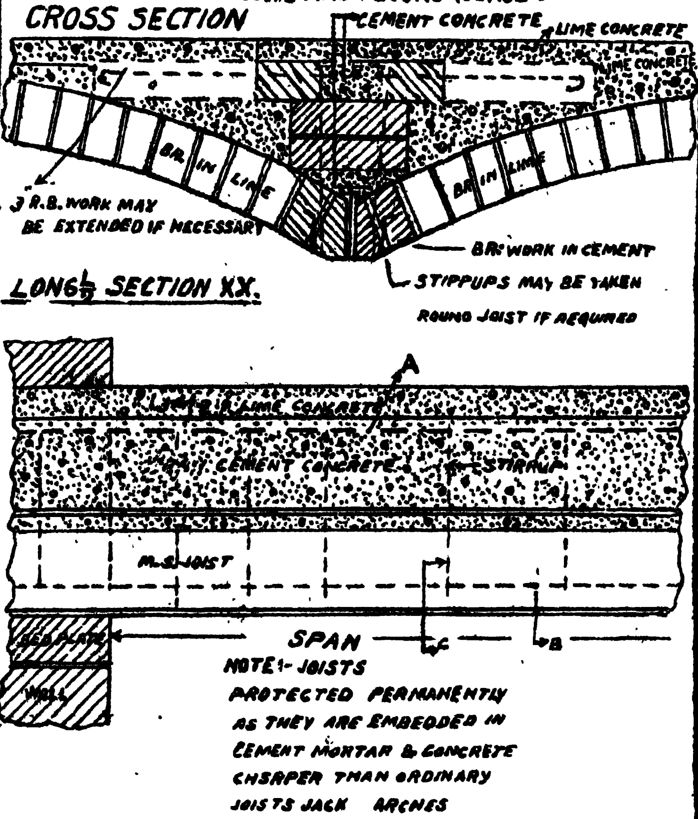


METHED OF STRENGTHING JOISTS IN JACK ARCH ROOFS AND FLOURS.

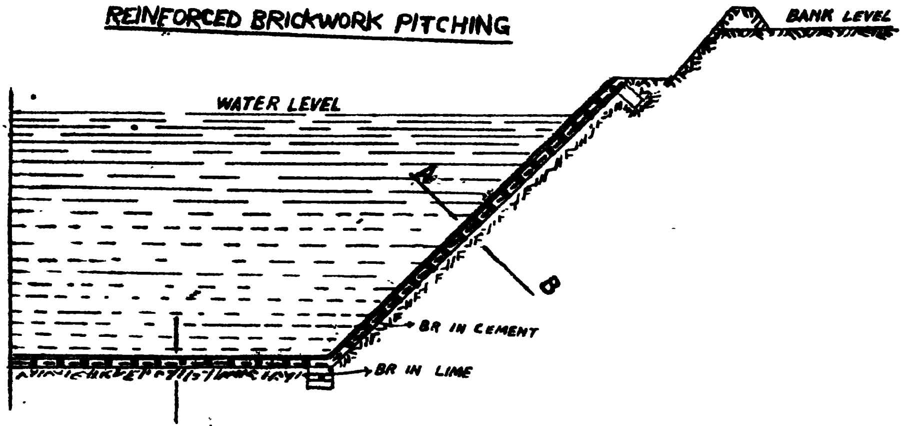
(CONTD)



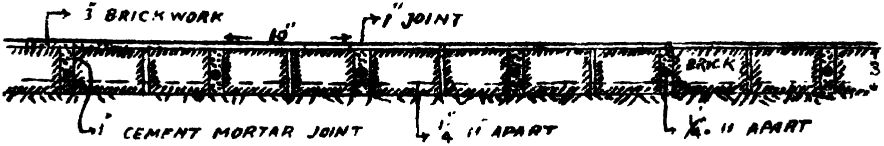
METHED OF STRENGTHING JOISTS IN JACK ARCH ROOFS AND FLOURS (CONCLD)



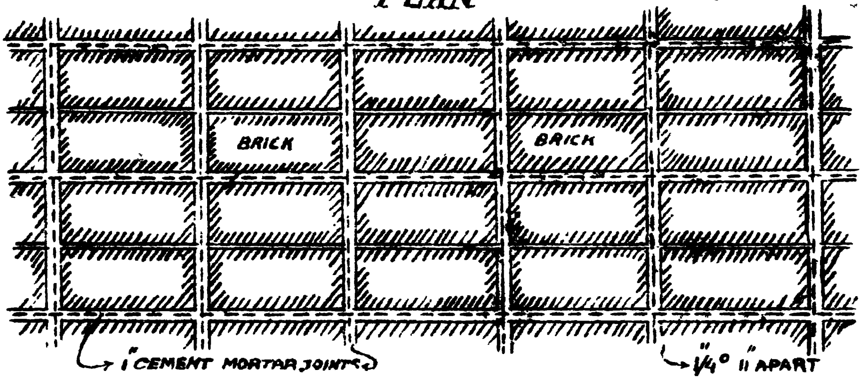
HALF SECTION OF A CHANNEL OR A RESERVOIR WITH 3" R. B. PITCHING OR LINING.



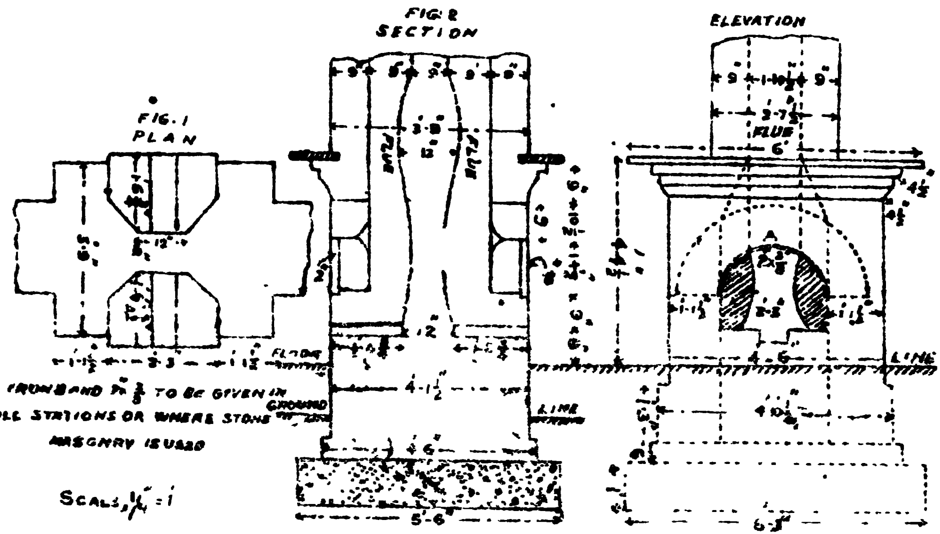
DETAILED CROSS SECTION



PLAN



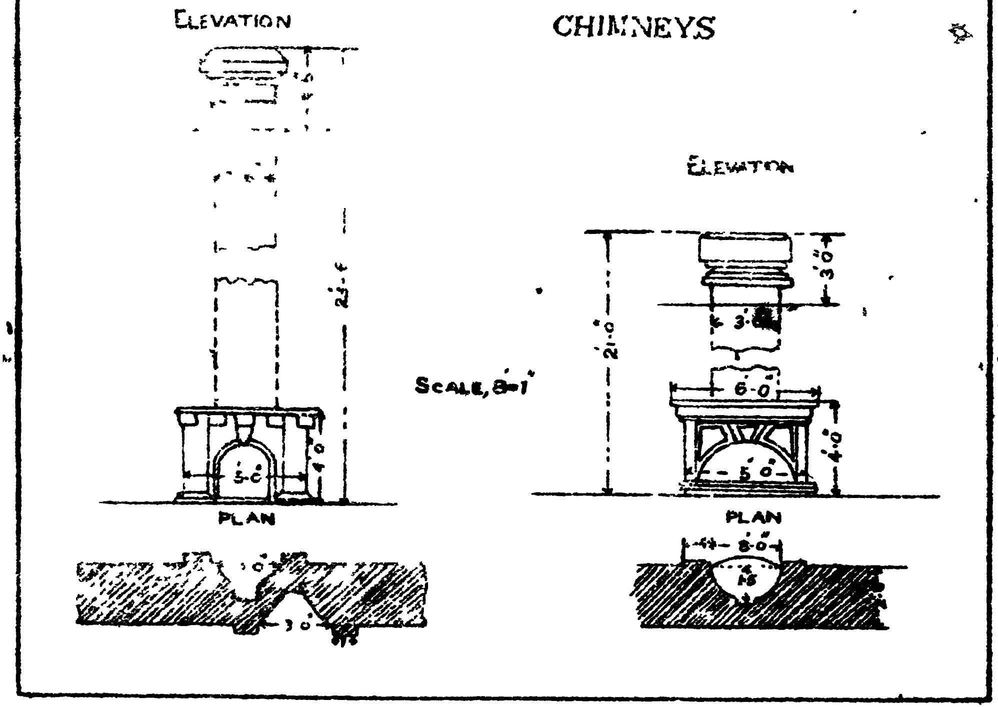
DOUBLE FIRE PLACE

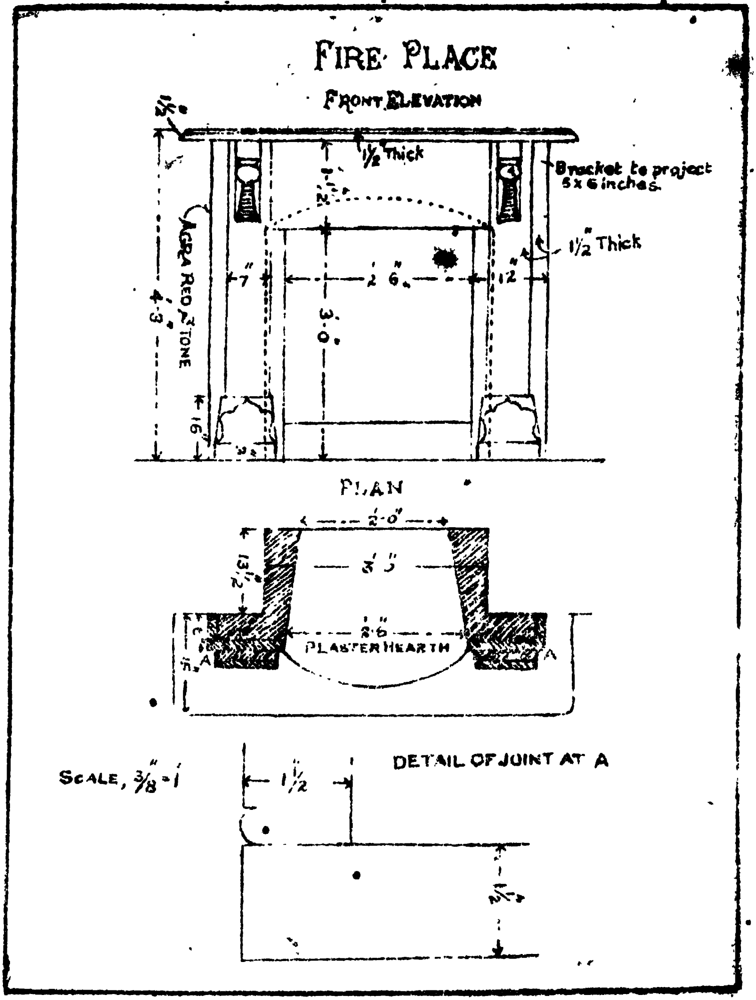


A IRON BAND ... TO BE GIVEN IN HILL STATIONS OR WHERE STONE MASONRY IS USED

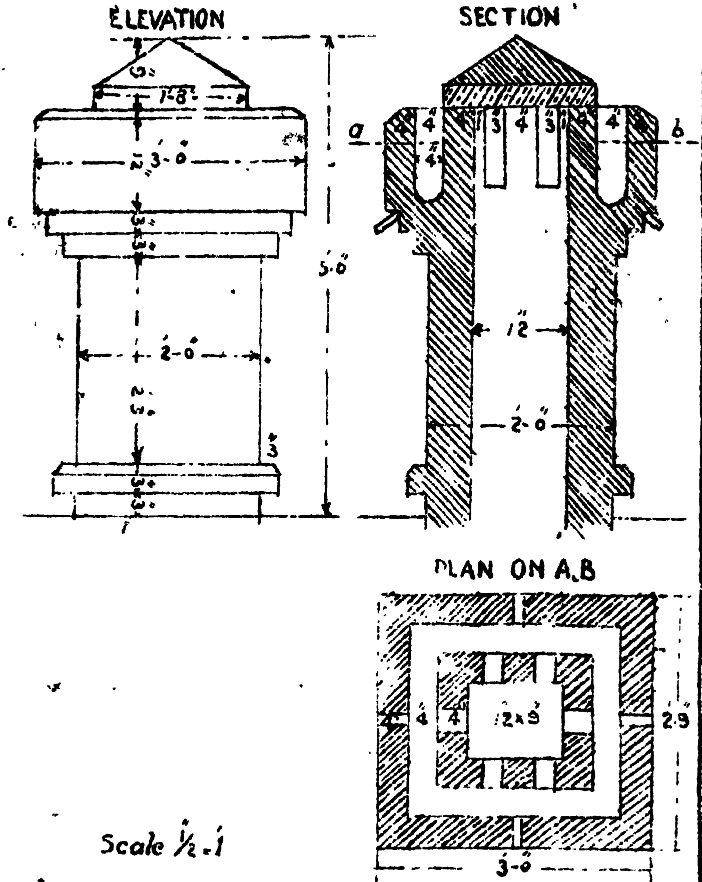
SCALE, 1/4" = 1'

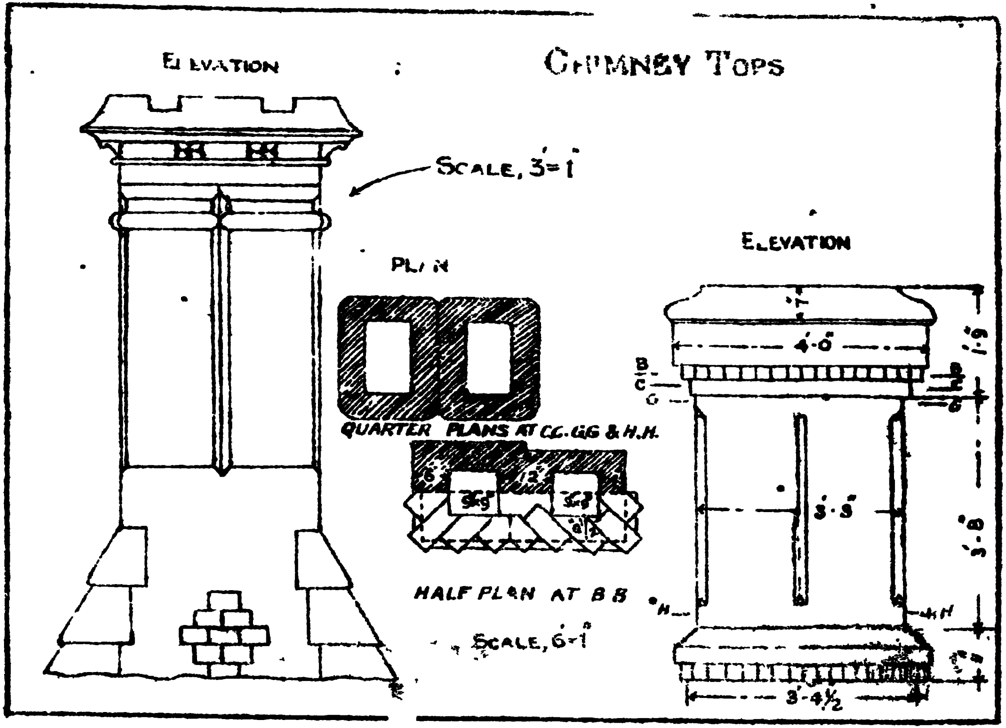
CHIMNEYS

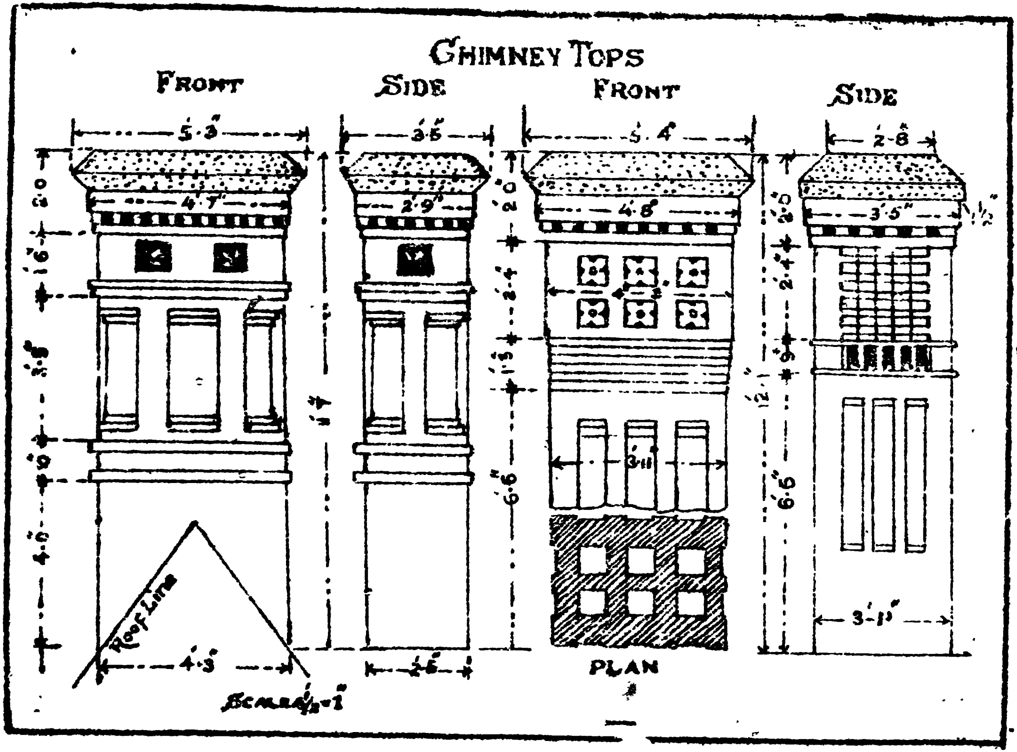



FIRE PLACE
FRONT ELEVATION
1½" Thick
Bracket to project 5 x 6 inches.
1½" Thick
AGRA RED STONE
PLAN
PLASTER HEARTH
SCALE, 3/8" = 1'
DETAIL OF JOINT AT A

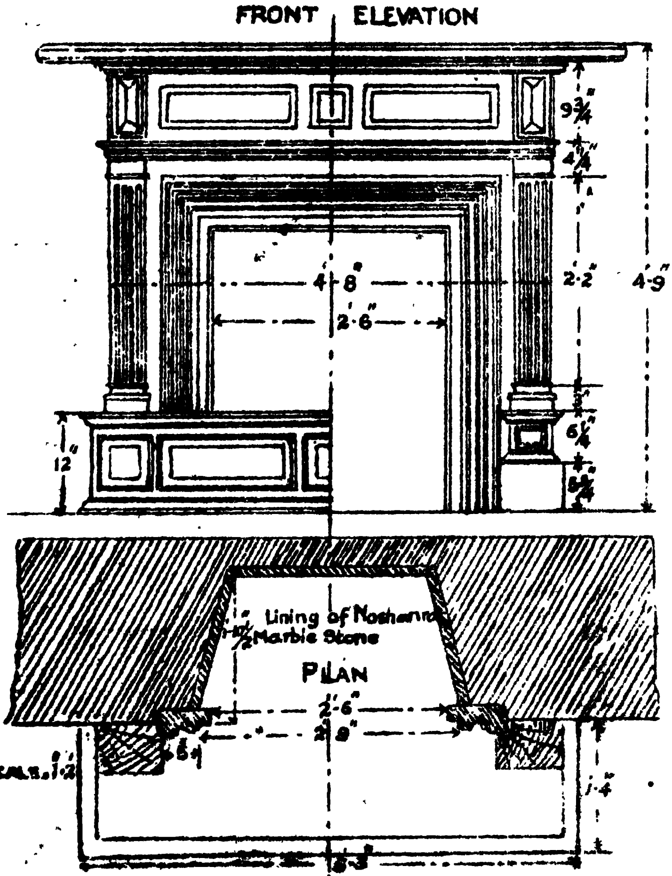
TOP OF CHIMNEY



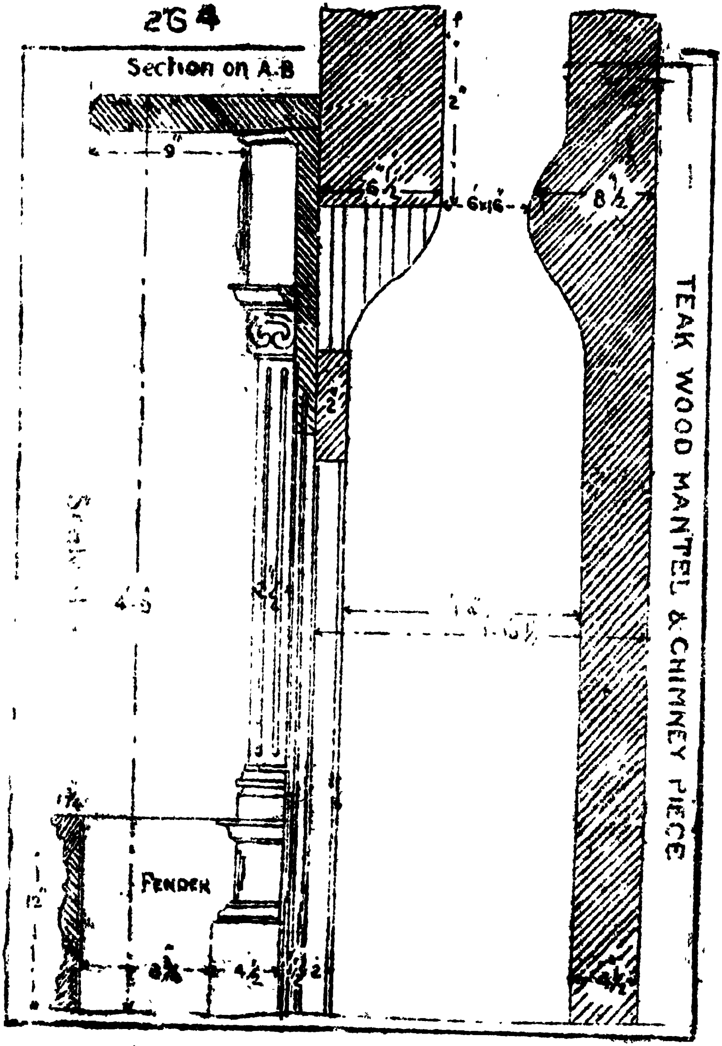

CHIMNEY TOPS
ELEVATION
SCALE, 3'=1"
PLAN
QUARTER PLANS AT CC. GG & H.H.
HALF PLAN AT B B
SCALE, 6'=1"
ELEVATION
4'·0"
3'·3"
3'·8"
3'·4½
1'·9
B
C
G
H
7


CHIMNEY TOPS
FRONT
SIDE
FRONT
SIDE
PLAN
Roof Line

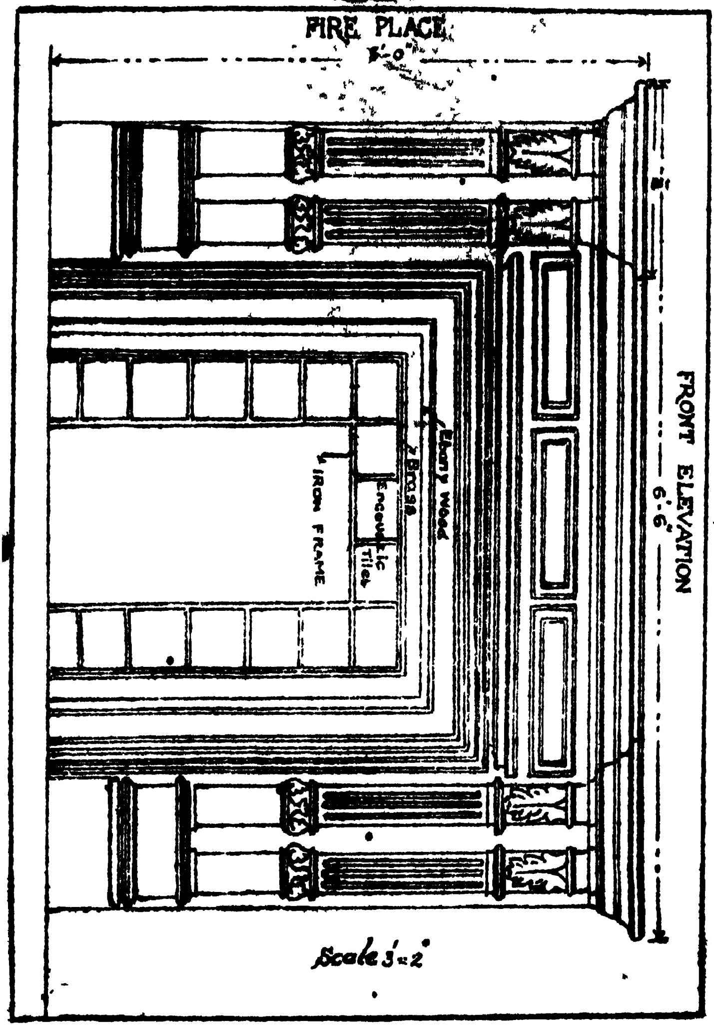
TEAK WOOD MANTEL & CHIMNEY PIECE



264



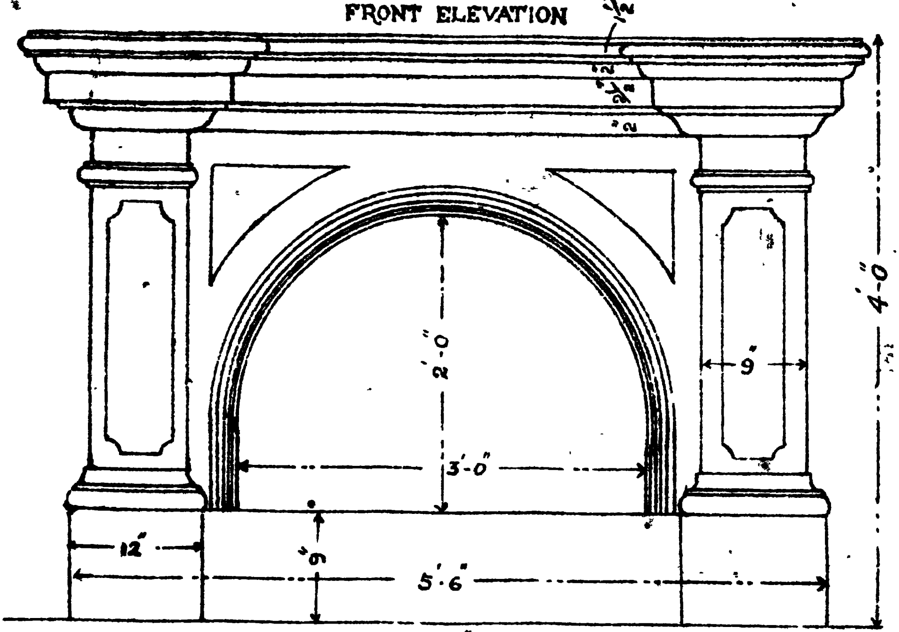
TEAK WOOD MANTEL & CHIMNEY PIECE



FIRE PLACE
5'-0"
FRONT ELEVATION
6'-6"
Ebony Wood
Brass
Encaustic Tiles
IRON FRAME
Scale 3'=2"

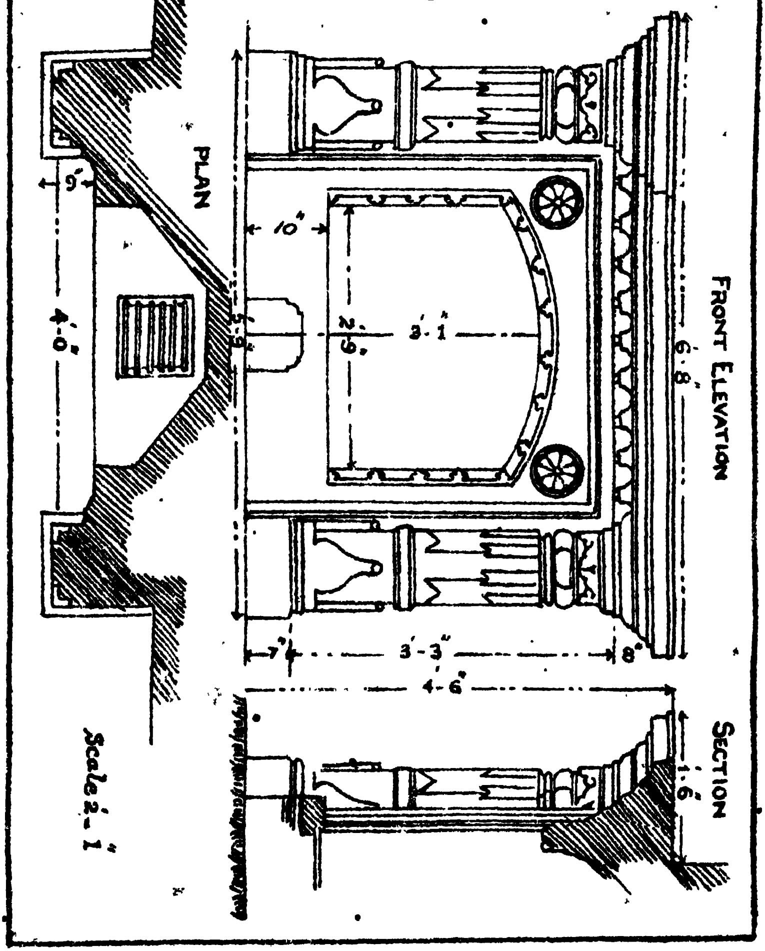
CHIMNEY.

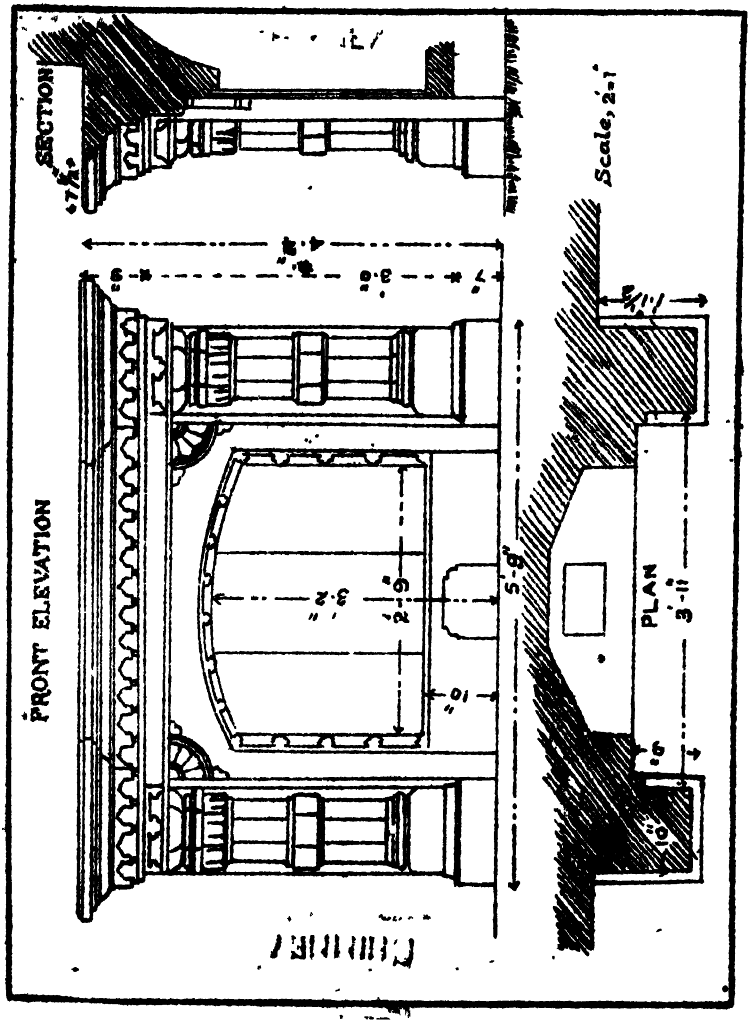
FRONT ELEVATION

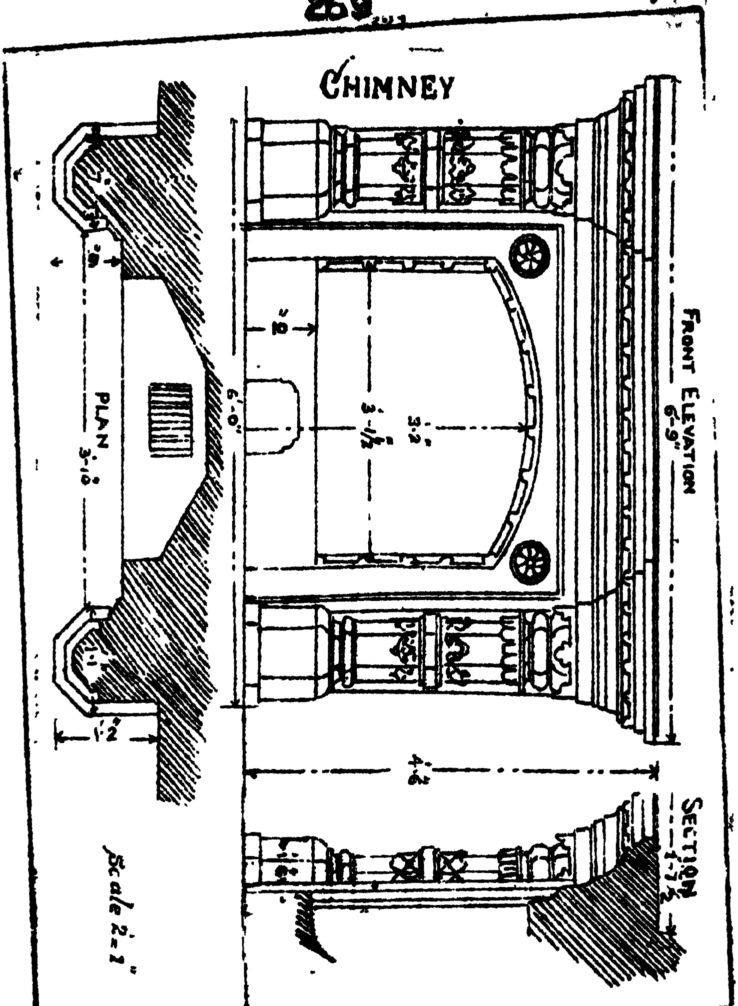


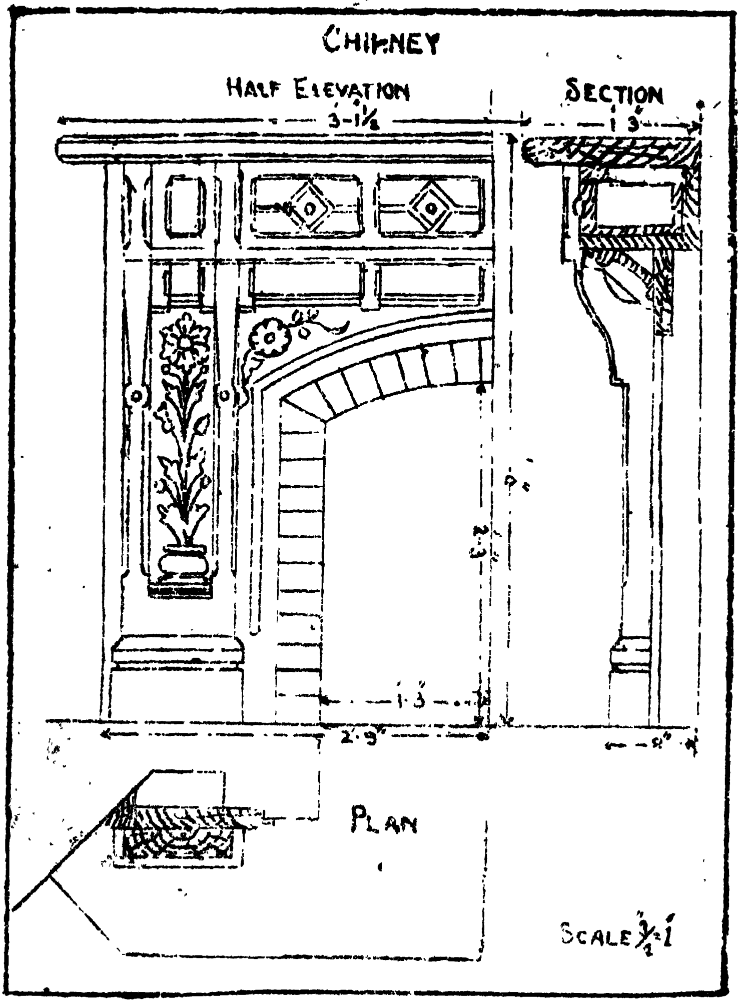
Scale 3/4" = 1'

CHIMNEY

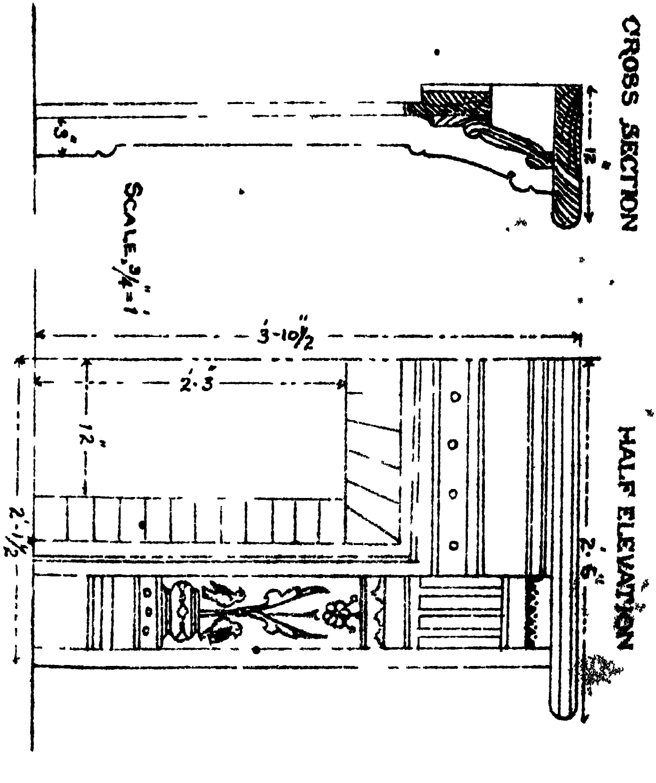

PLAN
FRONT ELEVATION
SECTION
Scale 2'-1"
6'-8"
4'-6"
4'-0"
3'-3"
3'-1"
2'-9"
1'-6"
10"
7"
8"


SECTION
FRONT ELEVATION
PLAN

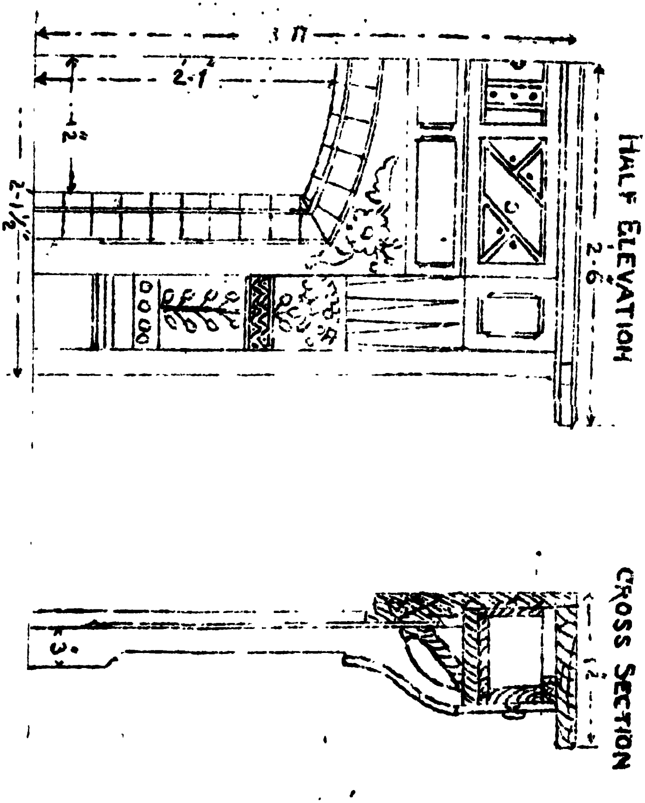

CHIMNEY
FRONT ELEVATION
6'-9"
PLAN
3'-10"
SECTION
1'-7½"
4'-6"
6'-0"
Scale 2'=1"


CHIMNEY
HALF ELEVATION
3-1½
SECTION
1 3
9
2 3
1·3
2·9
9
PLAN
SCALE ½"=1'

CHIMNEY



CHIMNEY

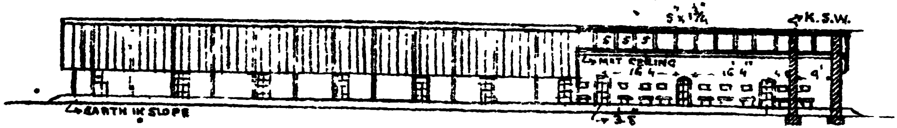


SCALE ¾ = 1'

MILITARY WORKS & BUILDINGS.

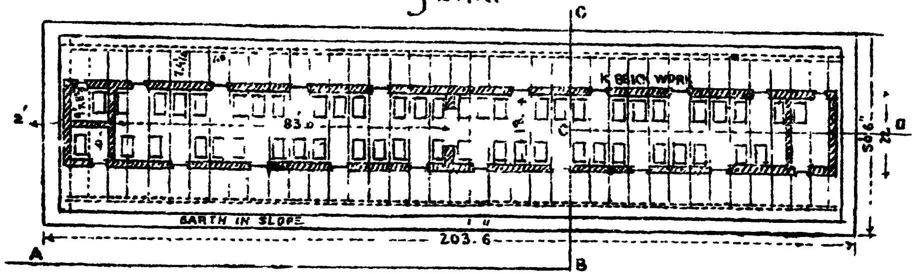
BARRACK FOR SINGLE 53 MEN

ELEVATION AND SECTION ON ABC D.

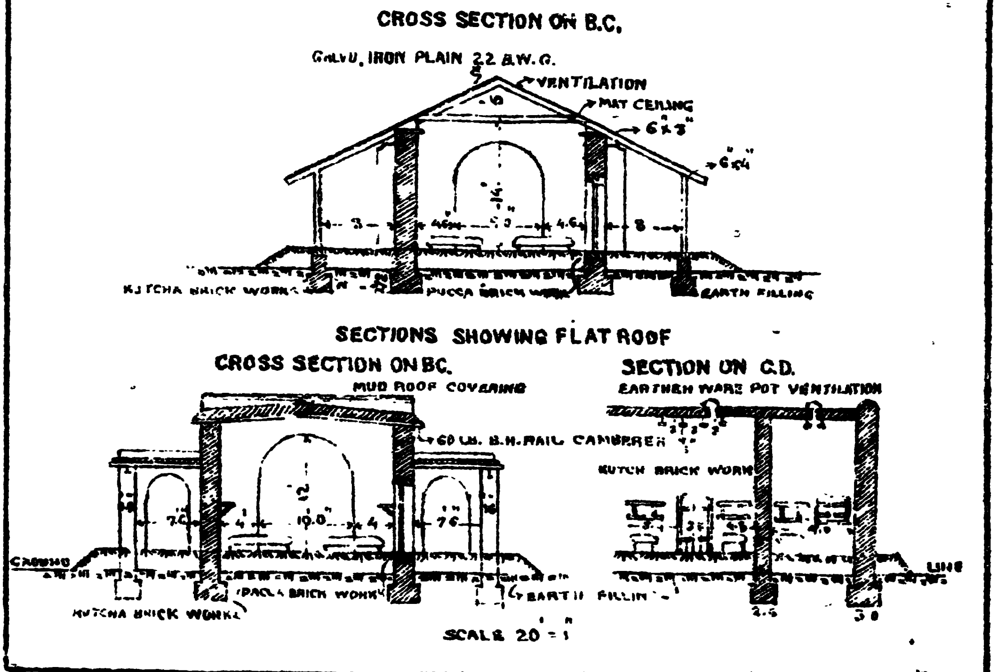


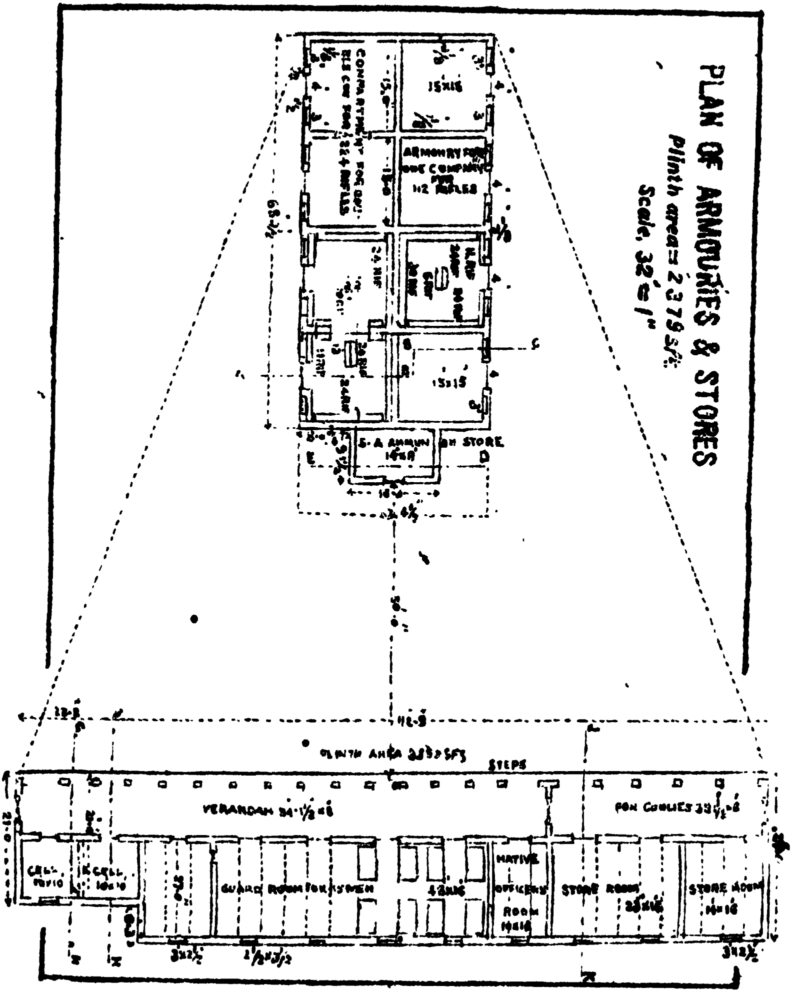
SCALE 50' = 1" INCH

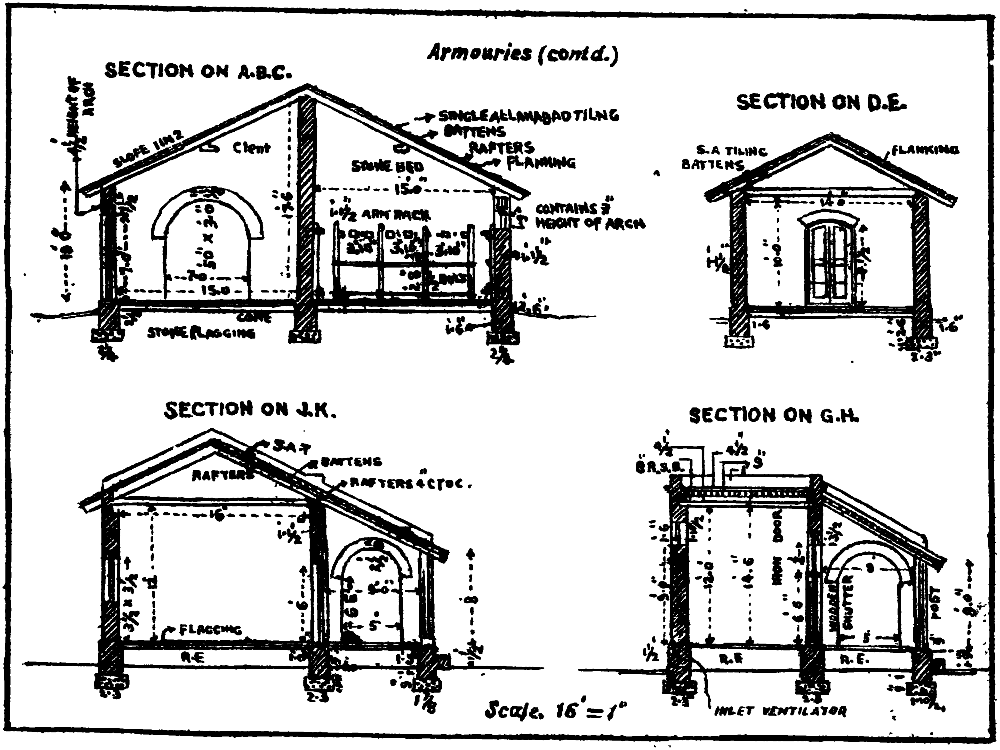
PLAN.



Barrack (contd.)



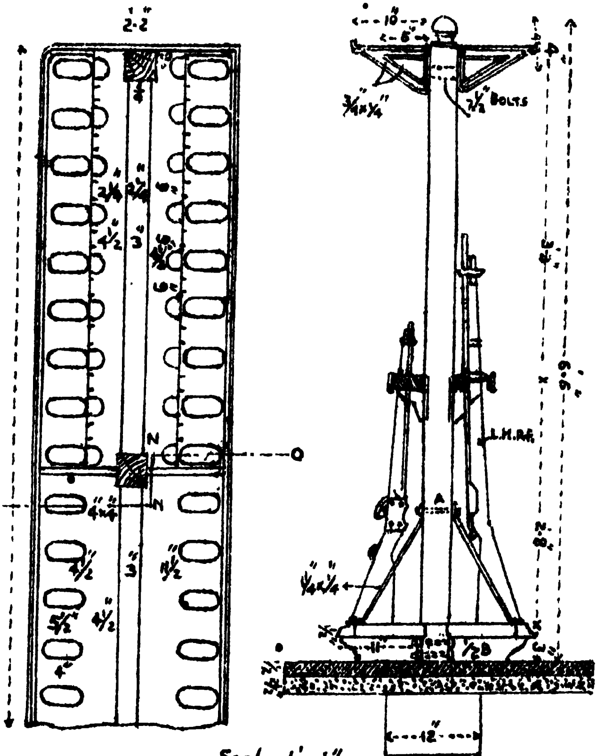

PLAN OF ARMOURIES & STORES
Plinth area = 2379 s/f.
Scale, 32' = 1"
ARMOURY FOR ONE COMPANY FOR 112 RIFLES
15x15
S. A. AMMUNITION STORE
VERANDAH
STEPS
FOR COOLIES
CELL
GUARD ROOM FOR 15 MEN
NATIVE OFFICERS ROOM
STORE ROOM
STORE ROOM


Armouries (contd.)
SECTION ON A.B.C.
HEIGHT OF ARCH
SLOPE 1 IN 2
Cleat
STONE BED
ARM RACK
SINGLE ALLAHABAD TILING
BATTENS
RAFTERS
FLANNING
CONTAINS HEIGHT OF ARCH
CORE
STONE FLAGGING
SECTION ON D.E.
S.A TILING
BATTENS
FLANKING
SECTION ON J.K.
S.A.T
BATTENS
RAFTERS
RAFTERS 4 C TO C.
FLAGGING
R.E
SECTION ON G.H.
B.R.S.B.
IRON DOOR
WOODEN SHUTTER
POST
R.E
R.E.
INLET VENTILATOR
Scale. 16' = 1"

Armouries (contd.)

DETAIL OF ARM RACK

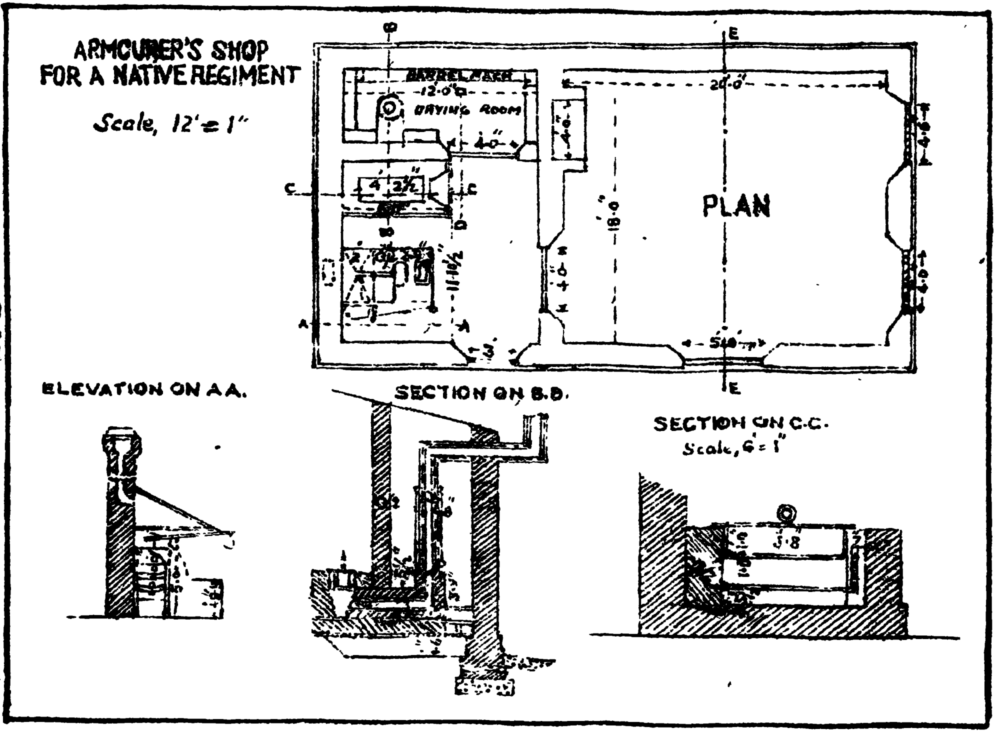
vide section on A BC.



Scale, 1' = ½"

ARMOURER'S SHOP FOR A NATIVE REGIMENT

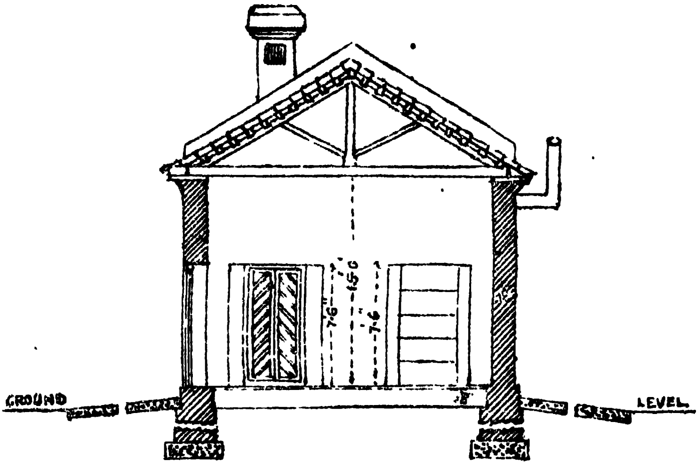
Scale, 12' = 1"



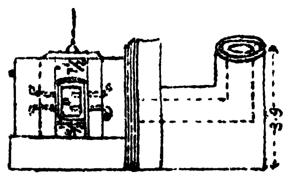
Armourer's shop (contd.)

SECTION ON E.E.

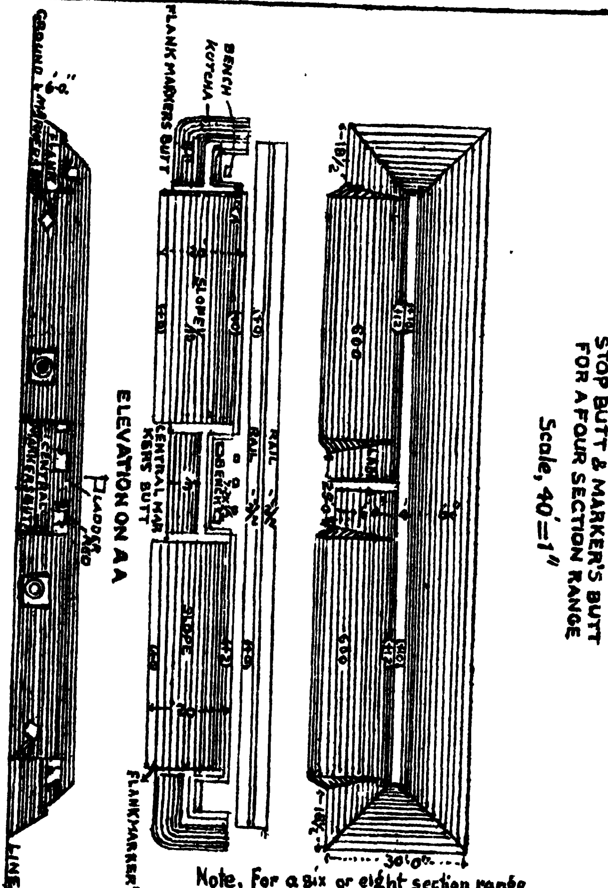
Scale, 12' = 1"



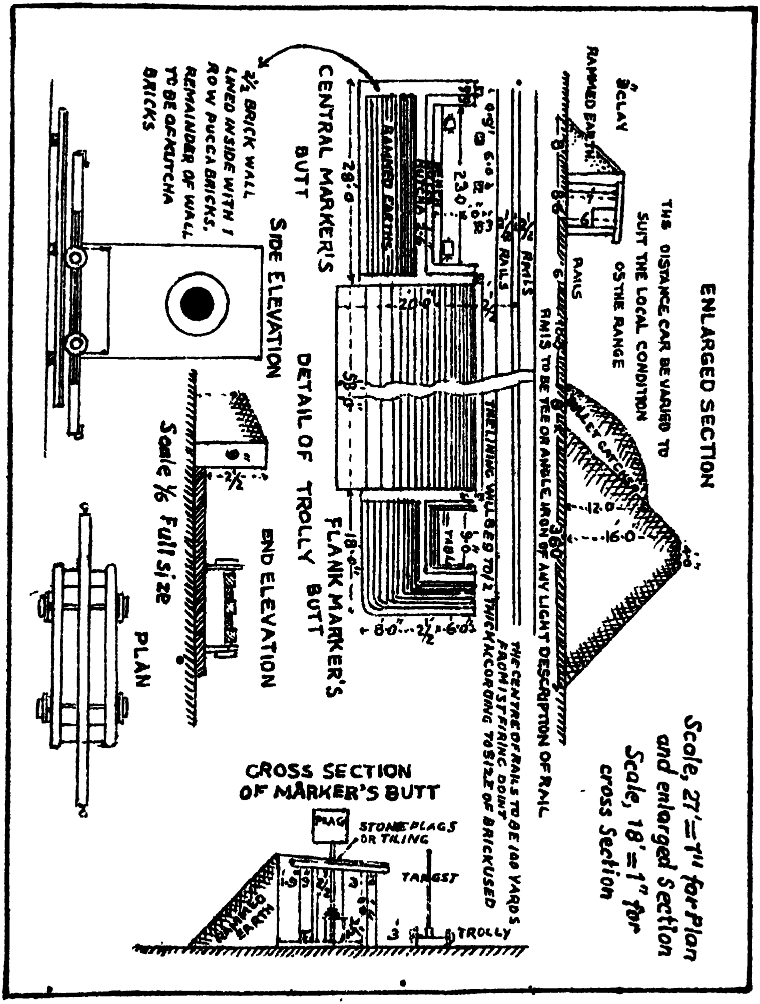
ELEVATION ON D.D.



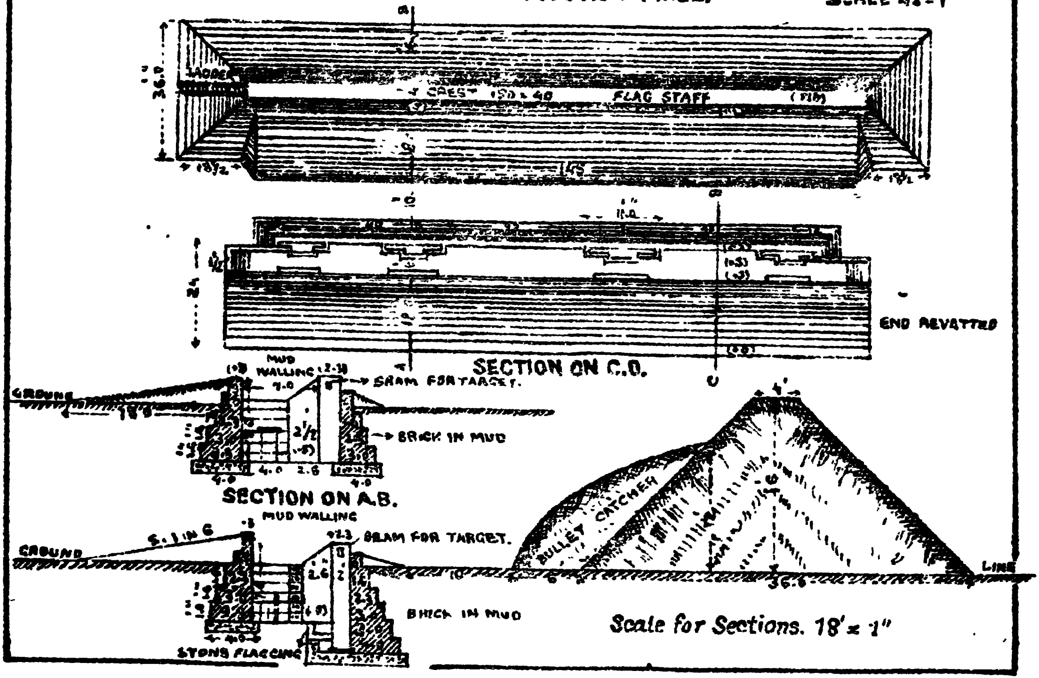
Scale. 6' = 1"

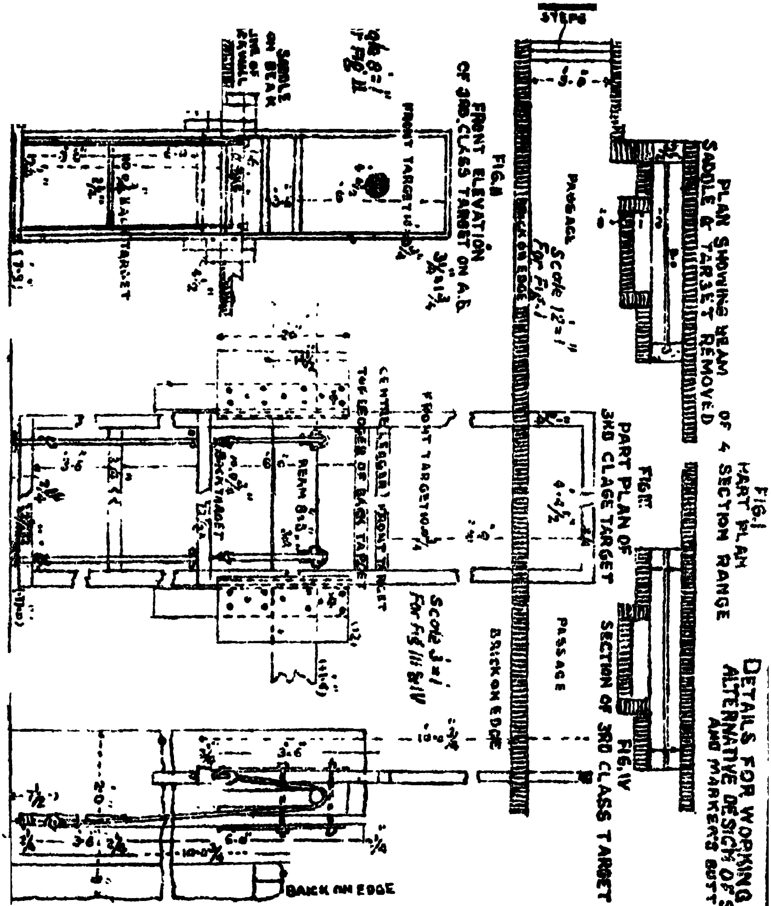


Note. For a six or eight section range length of stop butt will be broportion otaly increased. The detail being otherwise as in the standard plan.


ENLARGED SECTION
Scale, 27' = 1" for Plan and enlarged Section
Scale, 18' = 1" for cross Section
THE DISTANCE CAN BE VARIED TO SUIT THE LOCAL CONDITION OF THE RANGE
RAILS
RAILS TO BE TEE OR ANGLE IRON OF ANY LIGHT DESCRIPTION OF RAIL
THE CENTRE OF RAILS TO BE 100 YARDS FROM MISTFIRING POINT
THE LINING WILL BE 9 TO 12 THICK ACCORDING TO SIZE OF BRICK USED
BULLET CATCHER
RAMMED EARTH
RAMMED EARTH
CLAY
28'0"
23'0"
20'0"
38'0"
18'0"
12'0"
16'0"
360
CENTRAL MARKER'S BUTT
FLANK MARKER'S BUTT
2½ BRICK WALL LINED INSIDE WITH 1 ROW PUCCA BRICKS. REMAINDER OF WALL TO BE OF KUTCHA BRICKS
DETAIL OF TROLLY
SIDE ELEVATION
END ELEVATION
PLAN
Scale ⅙ Full size
CROSS SECTION OF MARKER'S BUTT
FLAG
STONE FLAGS OR TILING
TARGET
TROLLY
RAMMED EARTH

Alternative Design of
STOP BUTT & MARKER'S BUTT FOR A FOUR SECTION RANGE.





Note:- For a first & second class Targets the heights are the same as shown for a 3rd class Target (Fig II, III & IV). but frames will be 4' & 2' wider respectively

FIG V
ENLARGED PLAN SHOWING SADDLE & TARGET FRAME FIXED FOR 3RD CLASS TARGET.



FIG. VI.
PLAN OF SADDLE BEAM REMOVED

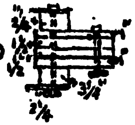


FIG VII.
SECTION OF SADDLE ON E.F.

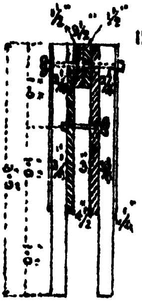
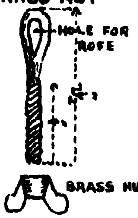


FIG. VIII
IRON BOLT WITH BRASS NUT



Scale, 2¼" = 1' for V to VII.

FIG IX.
ENLARGED PLAN AT C.C.

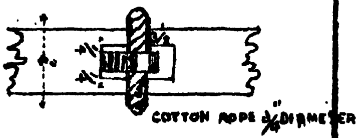


FIG X.
SECTION OF PULLY &c. ON K.L.

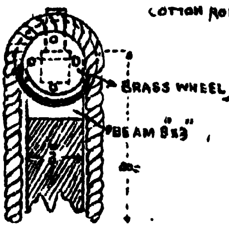
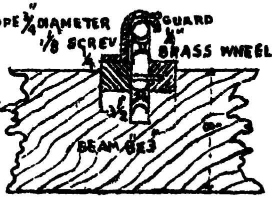
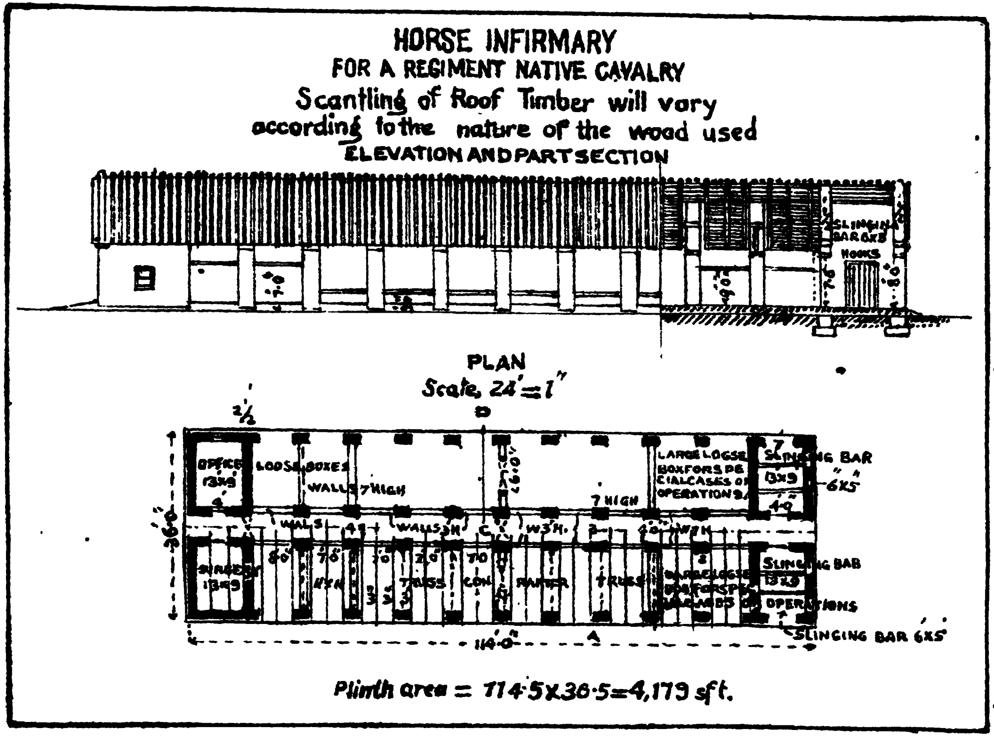
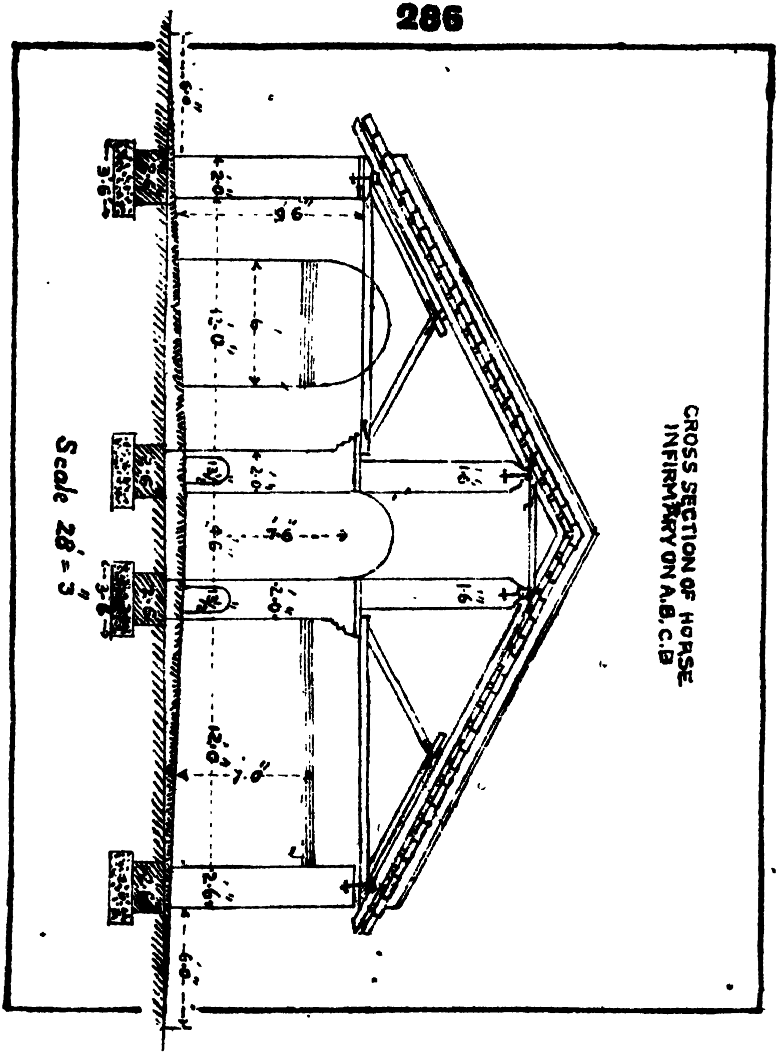


FIG XI.
SECTION OF PULLY ON I.J.
ELEVATION AND PART SECTION



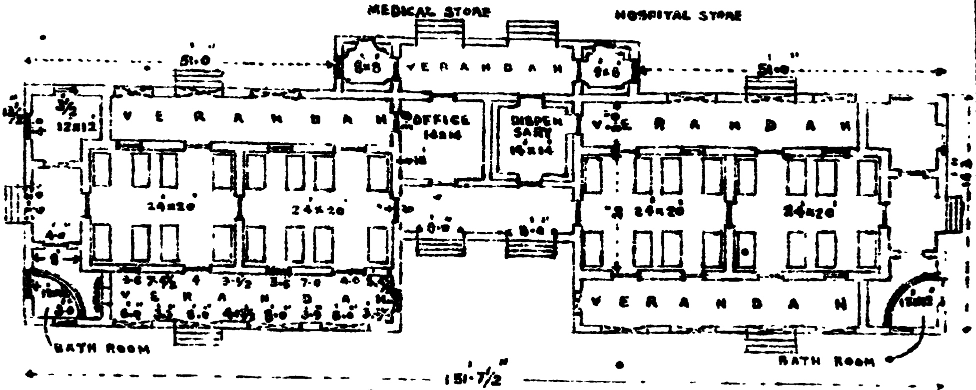
Scale, ⅓ full size for Figs. VIII to XI


HORSE INFIRMARY
FOR A REGIMENT NATIVE CAVALRY
Scantling of Roof Timber will vary
according to the nature of the wood used
ELEVATION AND PART SECTION
SLINGING BAR 6X5
HOOKS
PLAN
Scale, 24'=1"
OFFICE 13X9
LOOSE BOXES
WALLS 7 HIGH
7 HIGH
LARGE LOOSE BOX FOR SPECIAL CASES OR OPERATIONS
SLINGING BAR
13X9
6X5
SURGERY 13X9
TRUSS
RAFTER
SLINGING BAR
13X9
OPERATIONS
SLINGING BAR 6X5
114'-0"
Plinth area = 114·5X36·5=4,179 sft.


CROSS SECTION OF HORSE
INFIRMARY ON A.B. C.B
Scale 28' = 3"

HOSPITAL FOR A REGIMENT OF INDIAN GAVALRY
FOR 32 PATIENTS

Scale, 32' = 1"

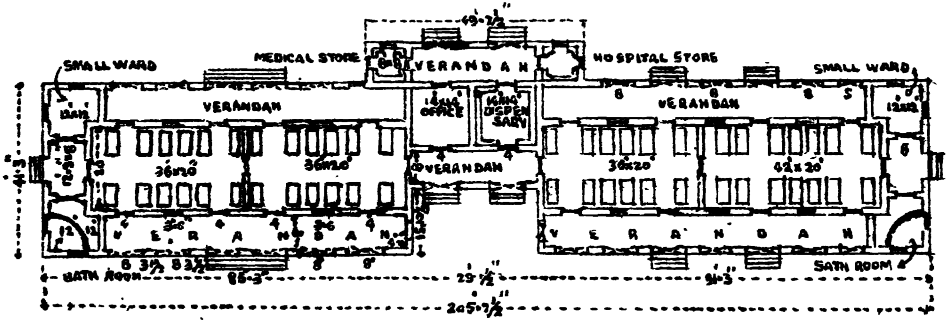


Plinth area = 6,332 sft.

Note.—3 Tiers of shelves to be given in dispensary and store rooms.

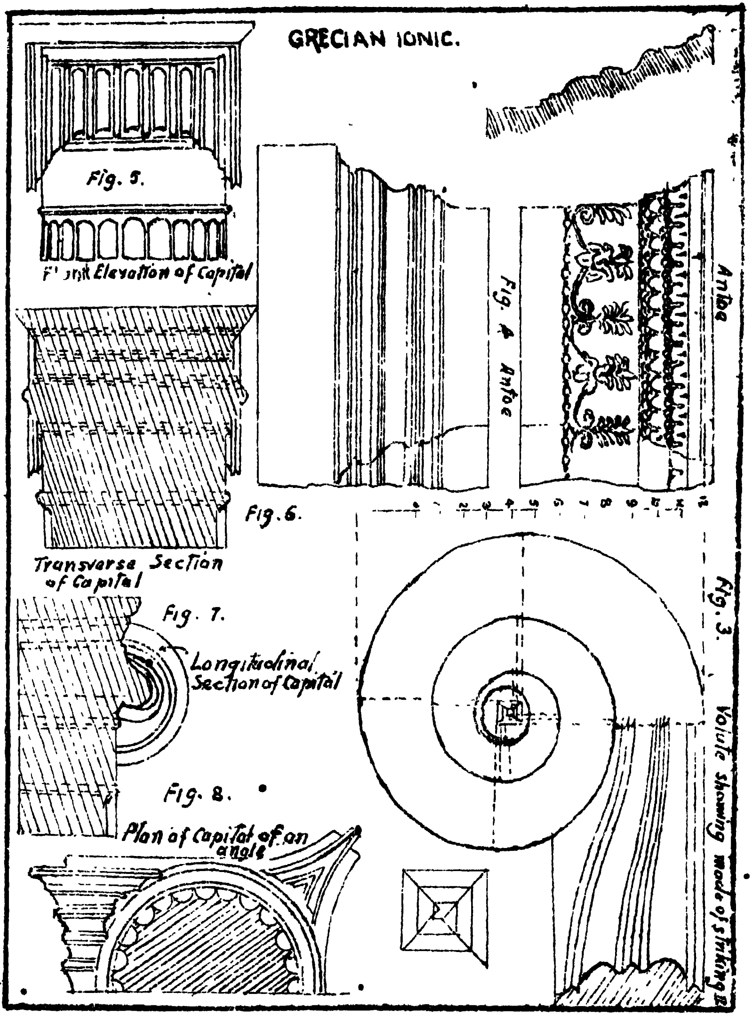
HOSPITAL FOR A REGIMENT OF INDIAN INFANTRY FOR 50 PATIENTS

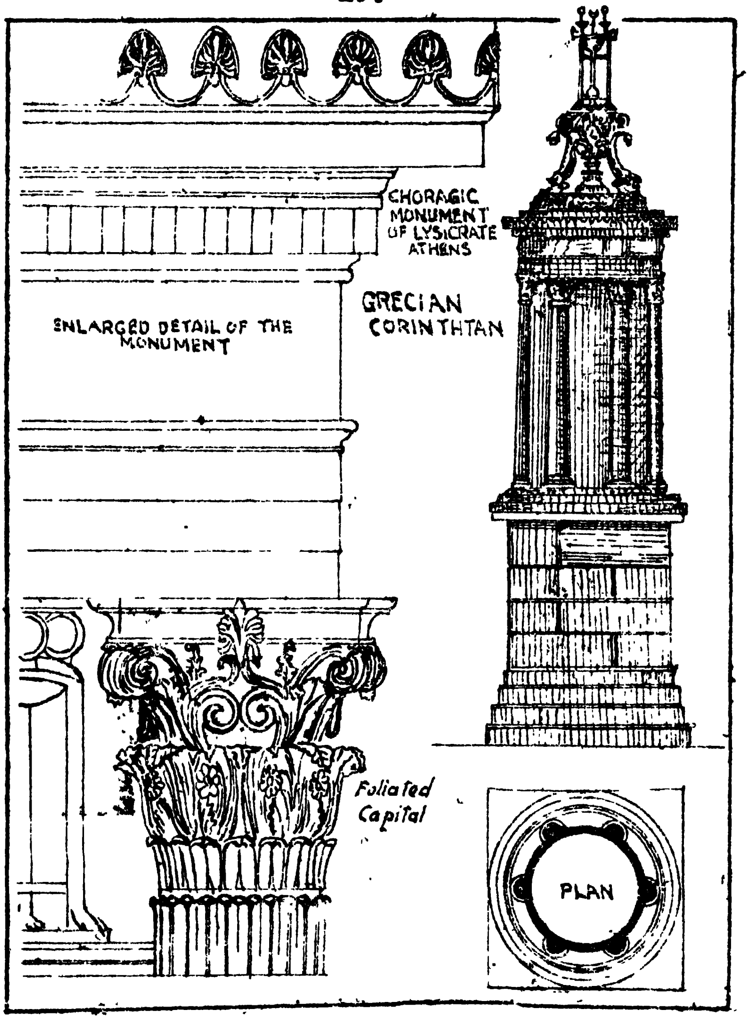
Scale 45' = 1"

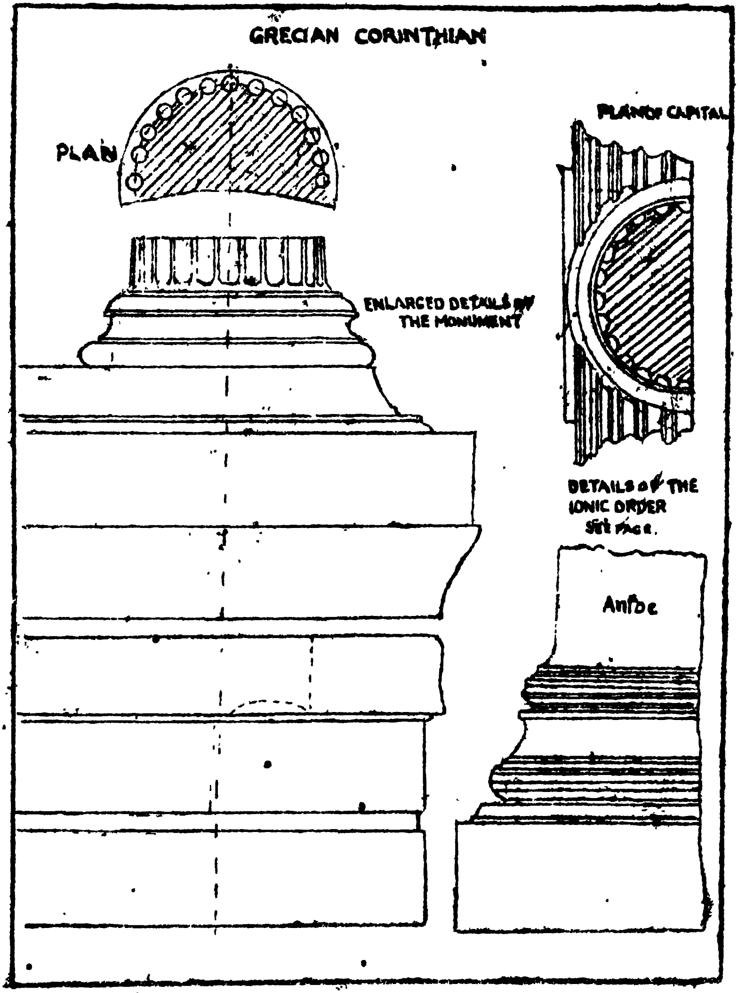


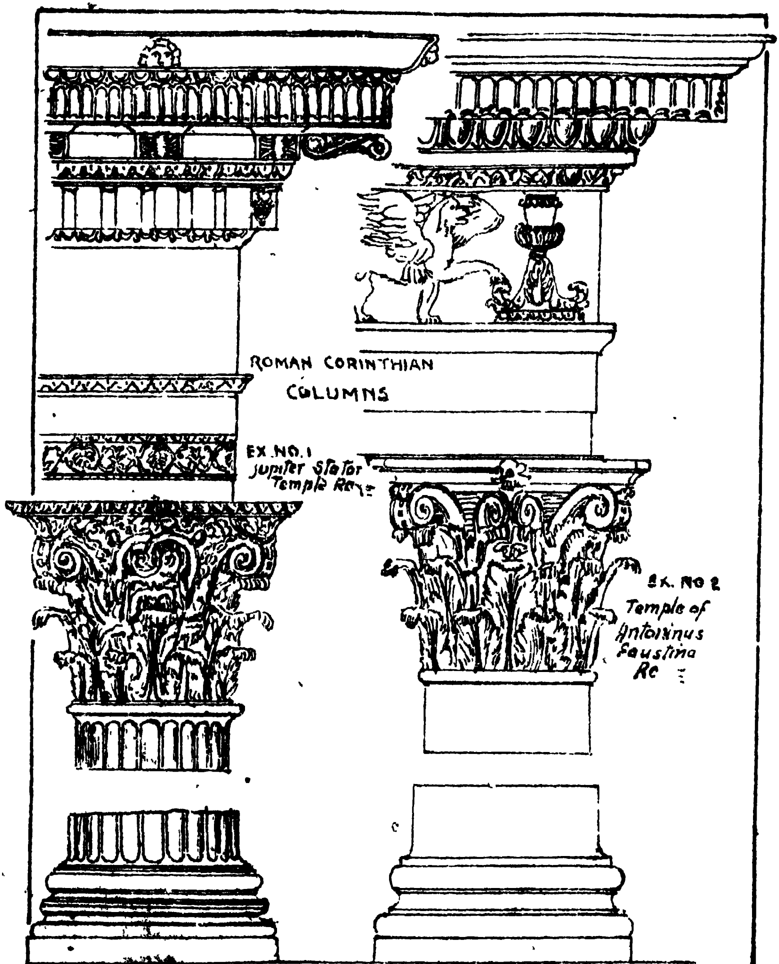
Plinth area = 8,580 sft.

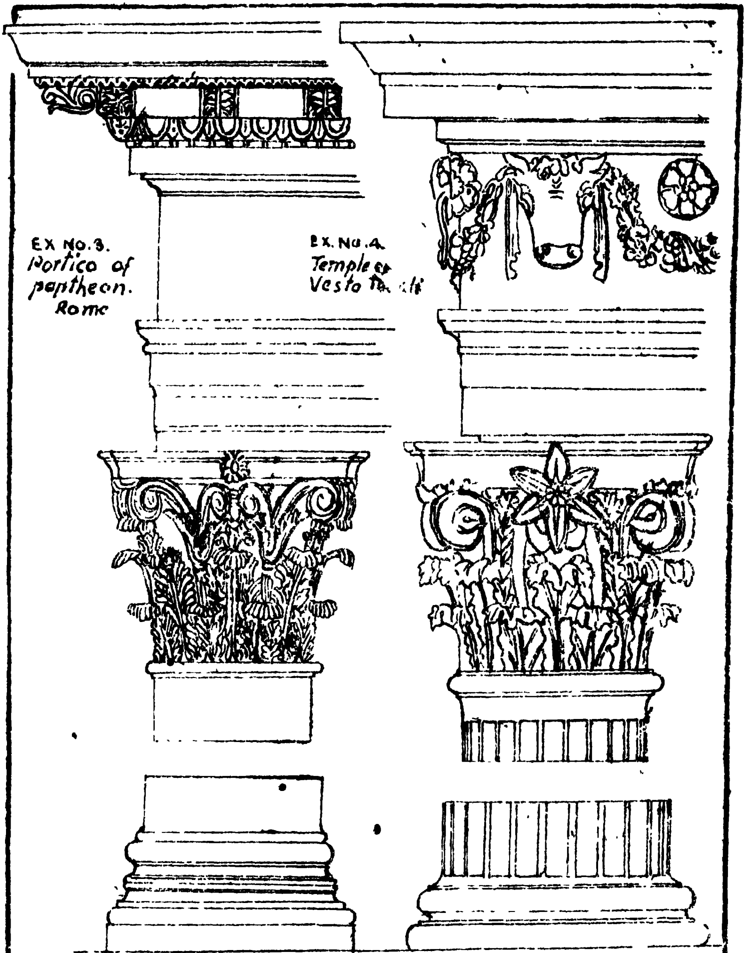
Note.—3 Tiers of shelves to be given in dispensary and store rooms


GRECIAN IONIC.
Fig. 5.
Front Elevation of Capital
Fig. 4 Antae
Antae
Fig. 6.
Transverse Section of Capital
Fig. 7.
Longitudinal Section of Capital
Fig. 3.
Volute showing mode of striking it
Fig. 8.
Plan of Capital of an angle

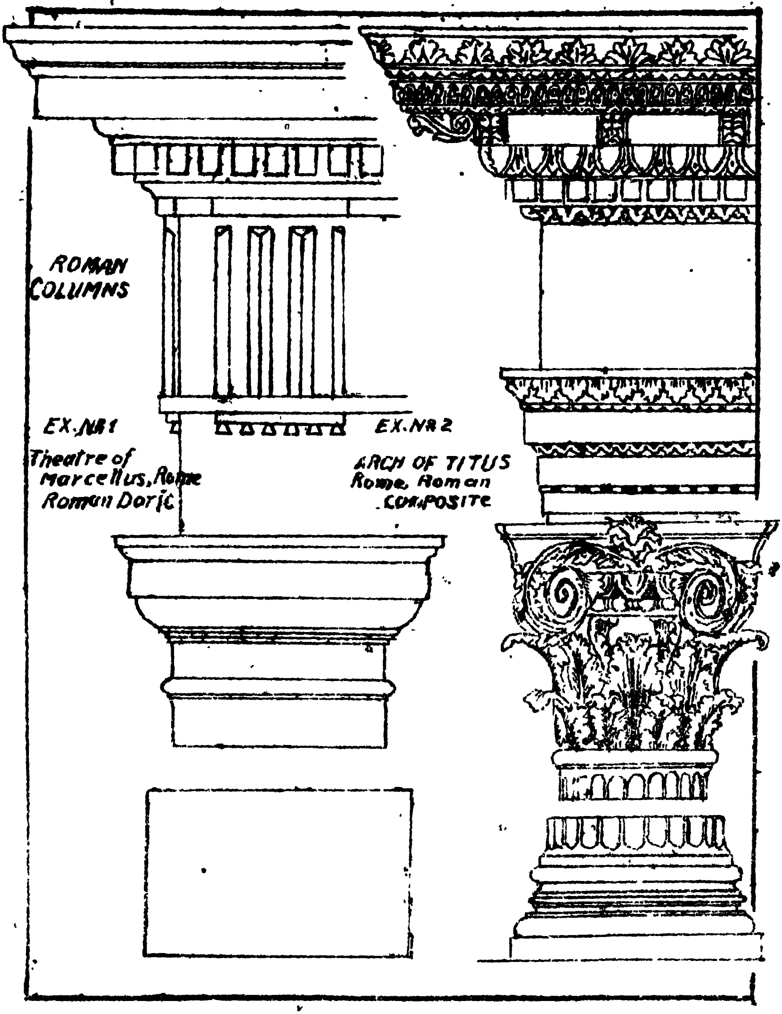

CHORAGIC MONUMENT OF LYSICRATE ATHENS
GRECIAN CORINTHTAN
ENLARGED DETAIL OF THE MONUMENT
Foliated Capital
PLAN

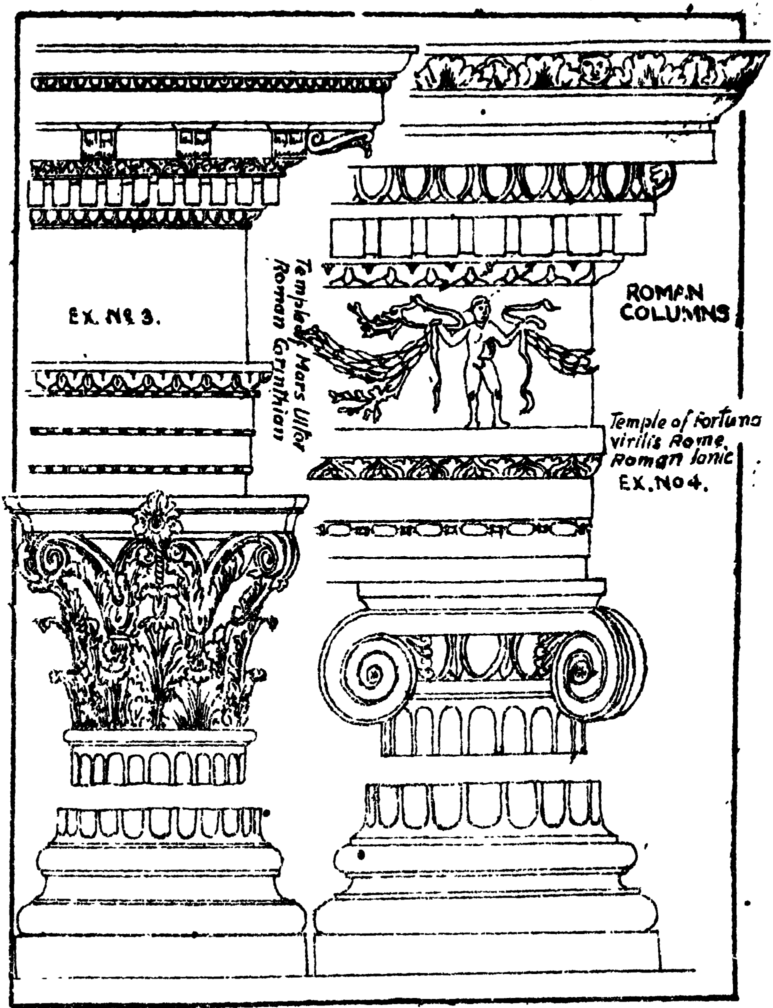

GRECIAN CORINTHIAN
PLAN
PLAN OF CAPITAL
ENLARGED DETAILS OF
THE MONUMENT
DETAILS OF THE
IONIC ORDER
SEE PAGE.

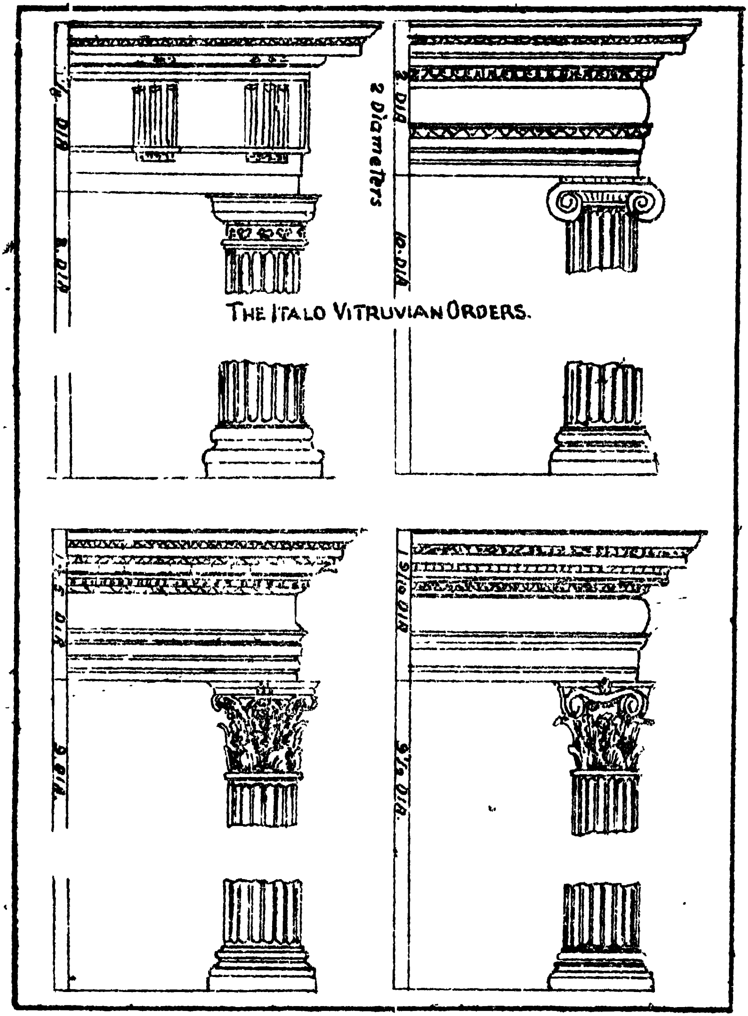

ROMAN CORINTHIAN
COLUMNS
EX. NO. 1
Jupiter Stator
Temple Rome
EX. NO 2
Temple of
Antoninus
Faustina
Rome

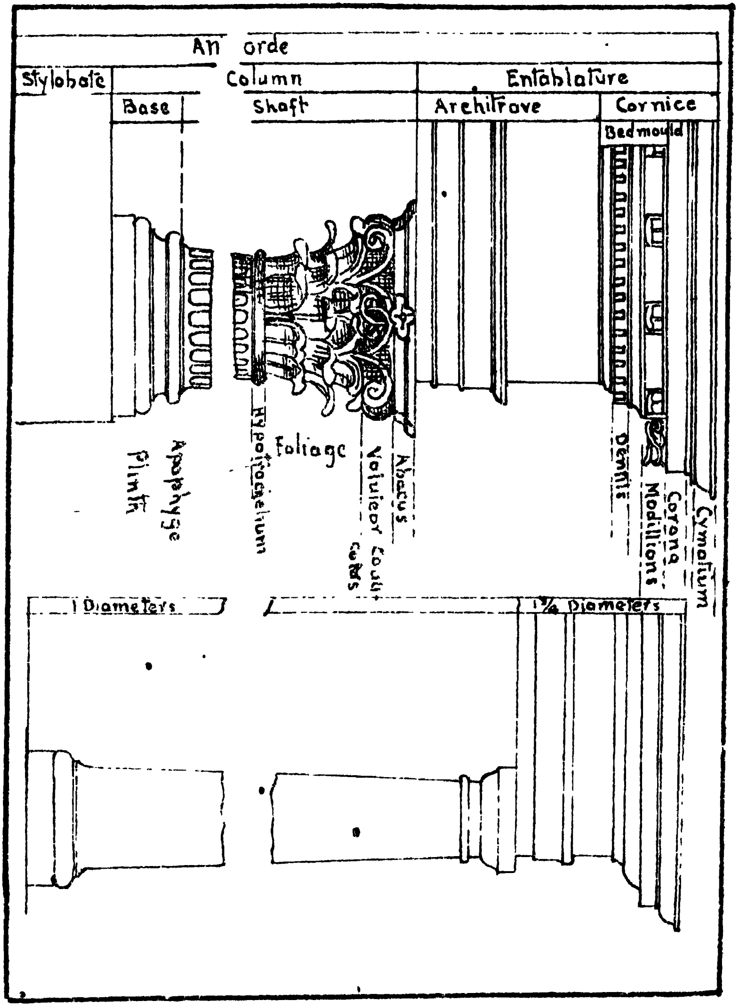


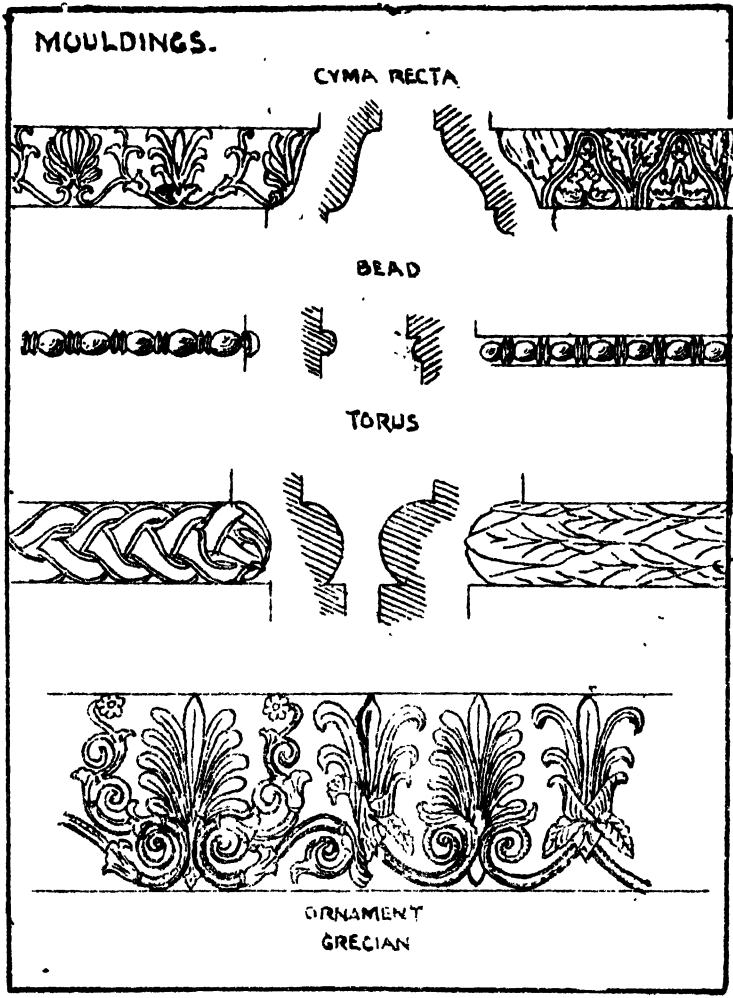
ROMAN CORINTHIAN COLUMNS.

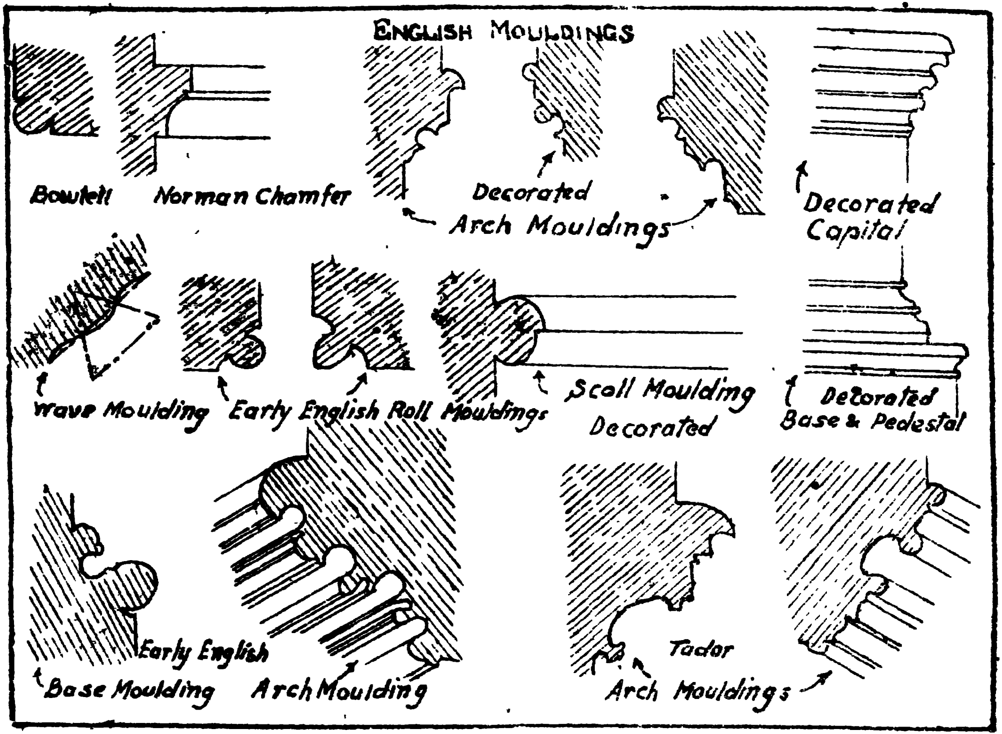

ROMAN COLUMNS
EX. NR 1
Theatre of Marcellus, Rome
Roman Doric
EX. NR 2
ARCH OF TITUS
Rome, Roman
COMPOSITE

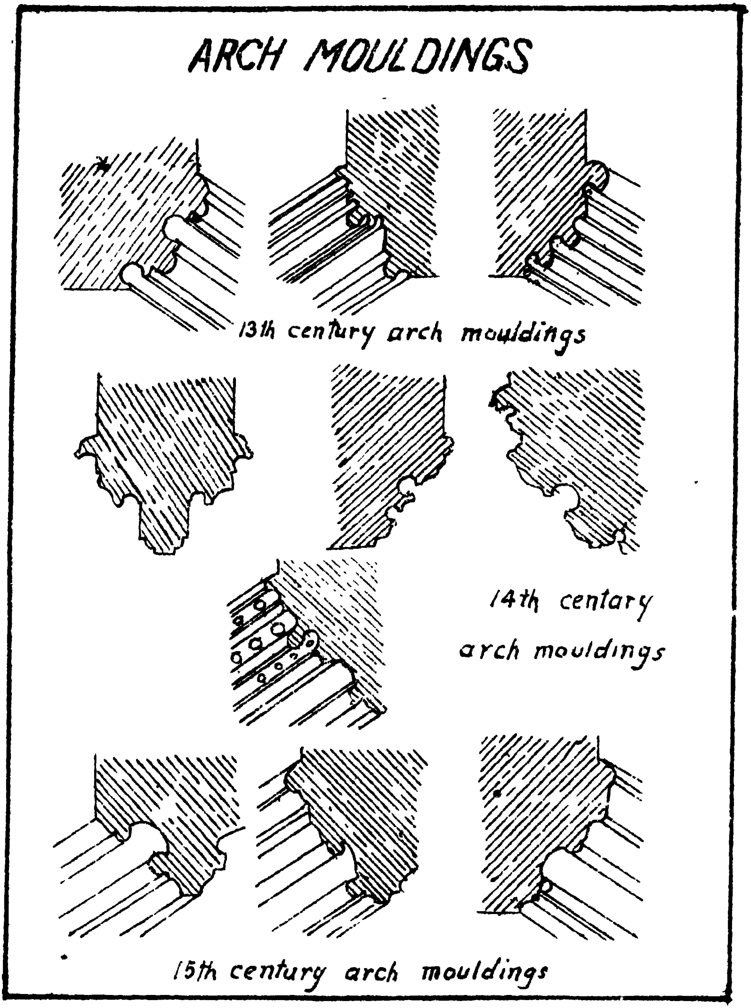

ROMAN COLUMNS
EX. No 3.
Temple of Mars Ultor Roman Corinthian
Temple of Fortuna virilis Rome. Roman Ionic
EX. No 4.

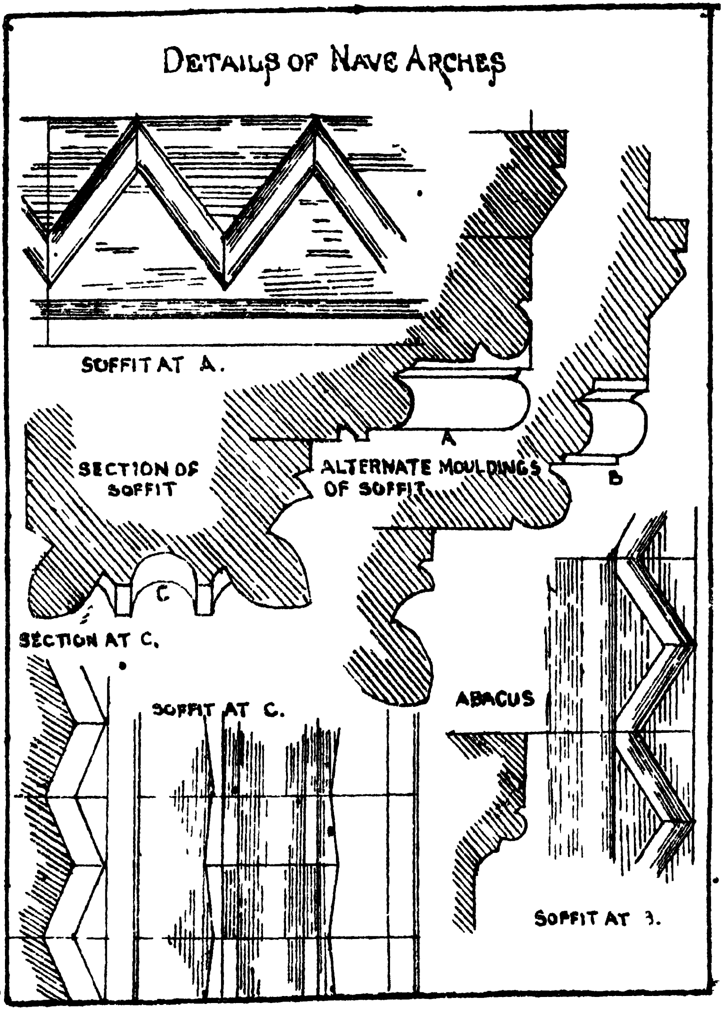

2 Diameters
THE ITALO VITRUVIAN ORDERS.

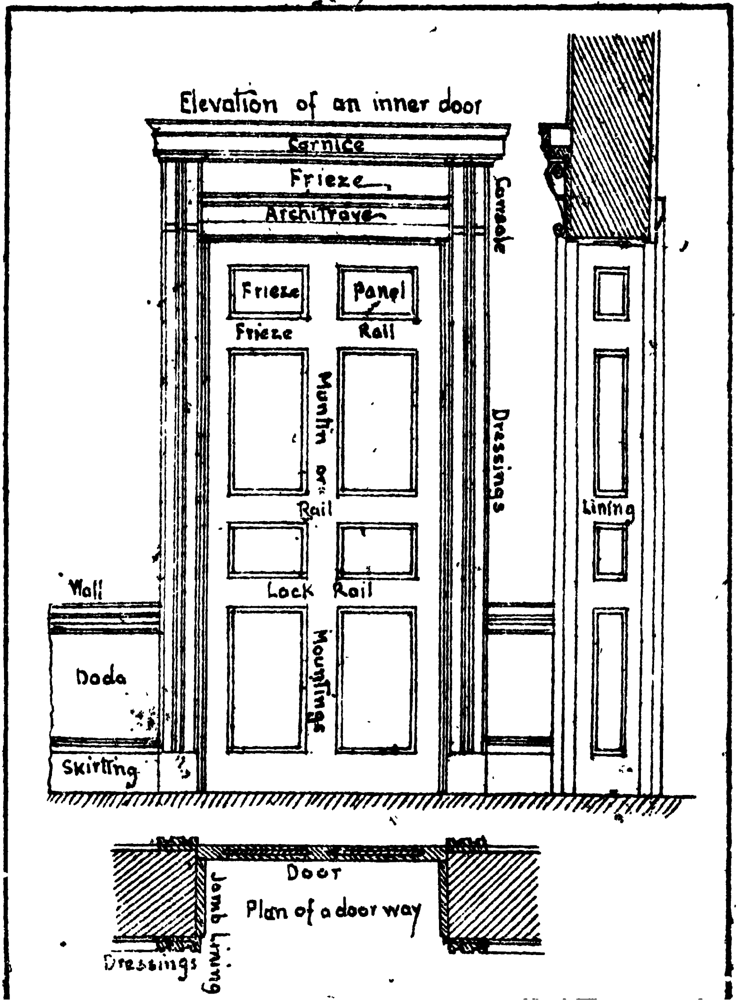

An orde
Stylobate
Column
Entablature
Base
Shaft
Architrave
Cornice
Bedmould
Plinth
Apophyge
Hypotrachelium
Foliage
Abacus
Dentils
Corona
Modillions
Cymatium
1 Diameters
1¾ Diameters

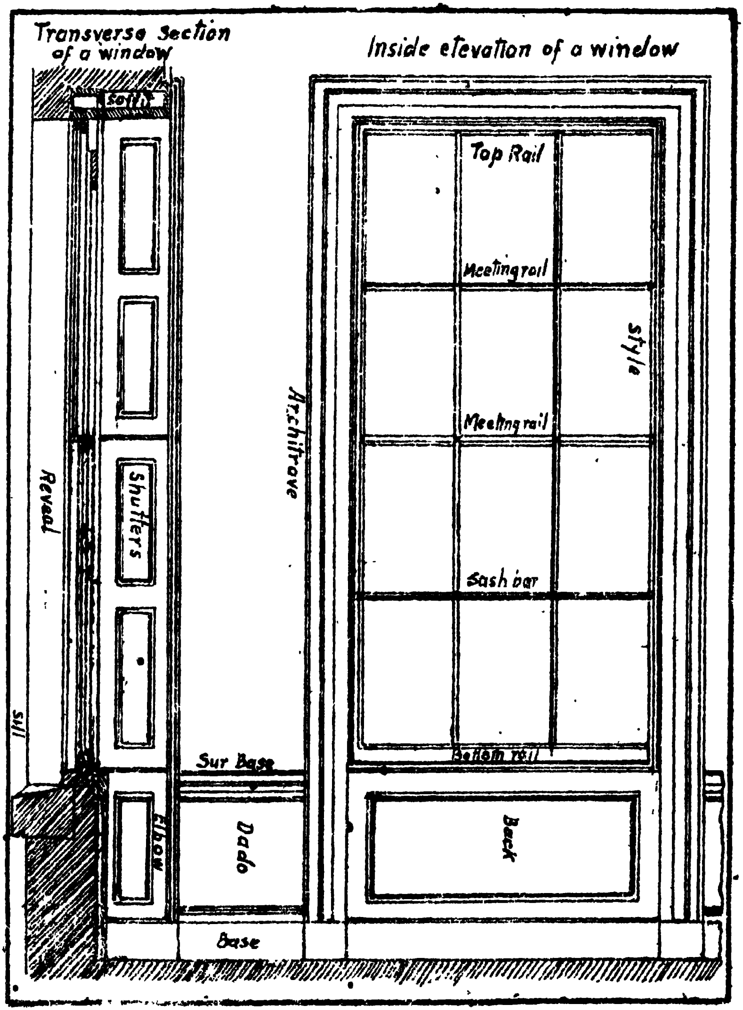

MOULDINGS.
CYMA RECTA
BEAD
TORUS
ORNAMENT
GRECIAN


ENGLISH MOULDINGS
Bowtell
Norman Chamfer
Decorated
Arch Mouldings
Decorated
Capital
Wave Moulding
Early English Roll Mouldings
Scoll Moulding
Decorated
Decorated
Base & Pedestal
Early English
Base Moulding
Arch Moulding
Tudor
Arch Mouldings

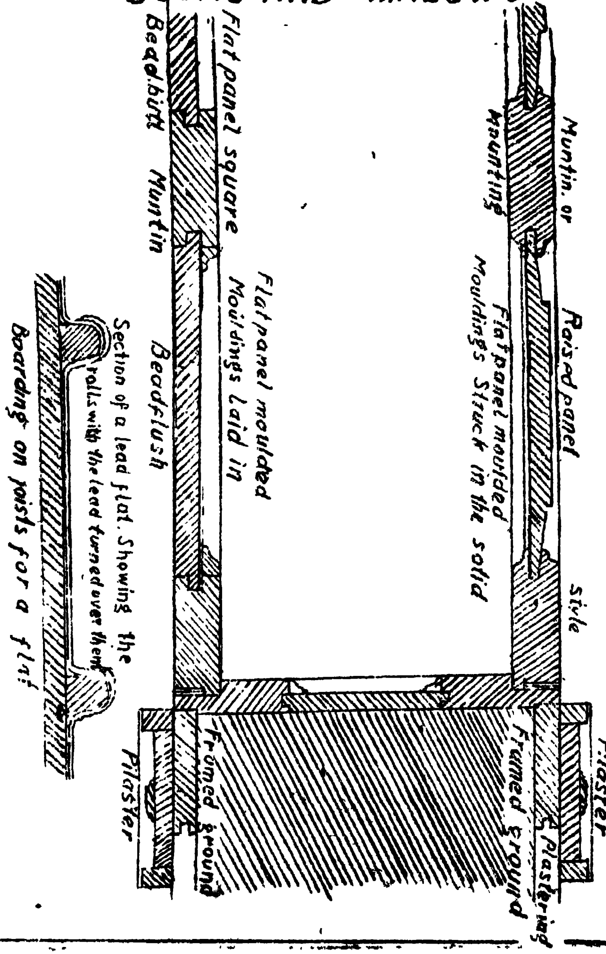

ARCH MOULDINGS
13th century arch mouldings
14th centary
arch mouldings
15th century arch mouldings

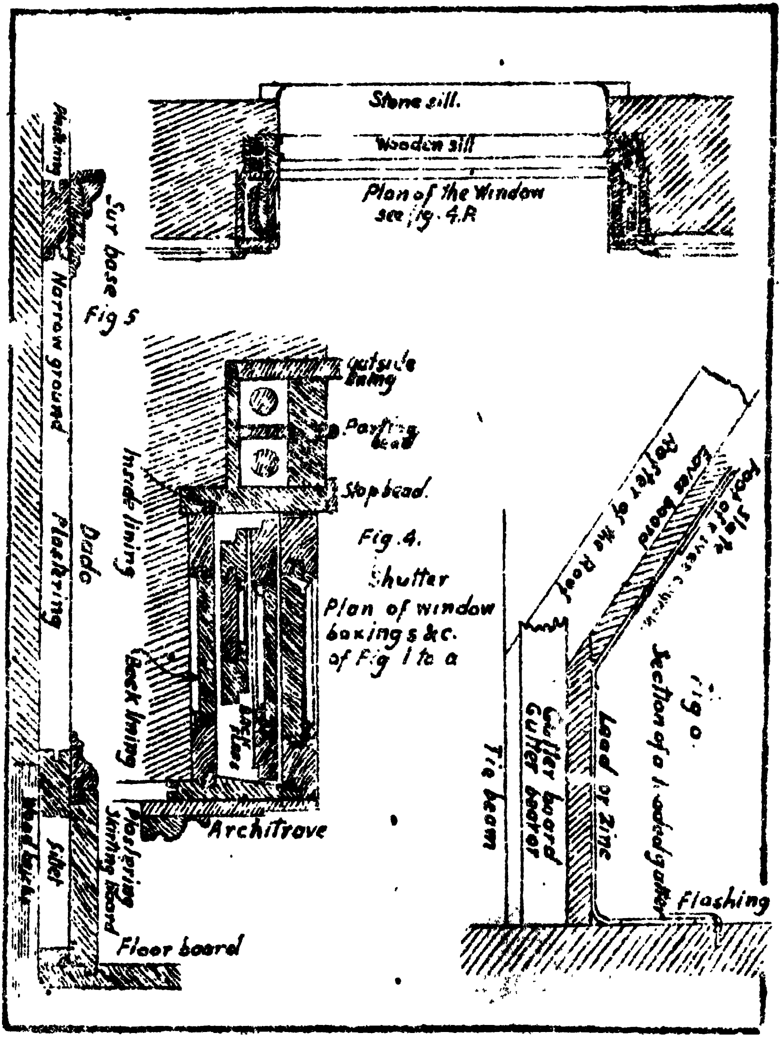

DETAILS OF NAVE ARCHES
SOFFIT AT A.
SECTION OF SOFFIT
ALTERNATE MOULDINGS OF SOFFIT
A
B
C
SECTION AT C.
SOFFIT AT C.
ABACUS
SOFFIT AT B.

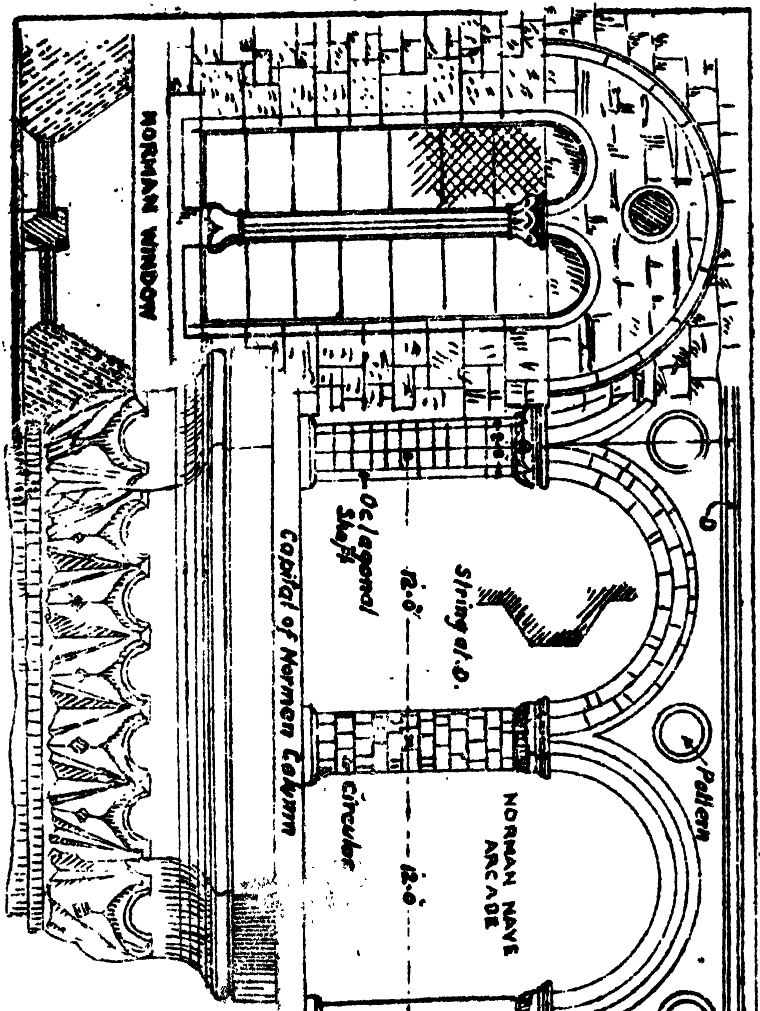

Elevation of an inner door
Cornice
Frieze
Architrave
Console
Frieze
Panel
Frieze
Rail
Muntin or
Rail
Dressings
Lining
Wall
Lock Rail
Dado
Mountings
Skirting
Door
Plan of a door way
Jamb Lining
Dressings

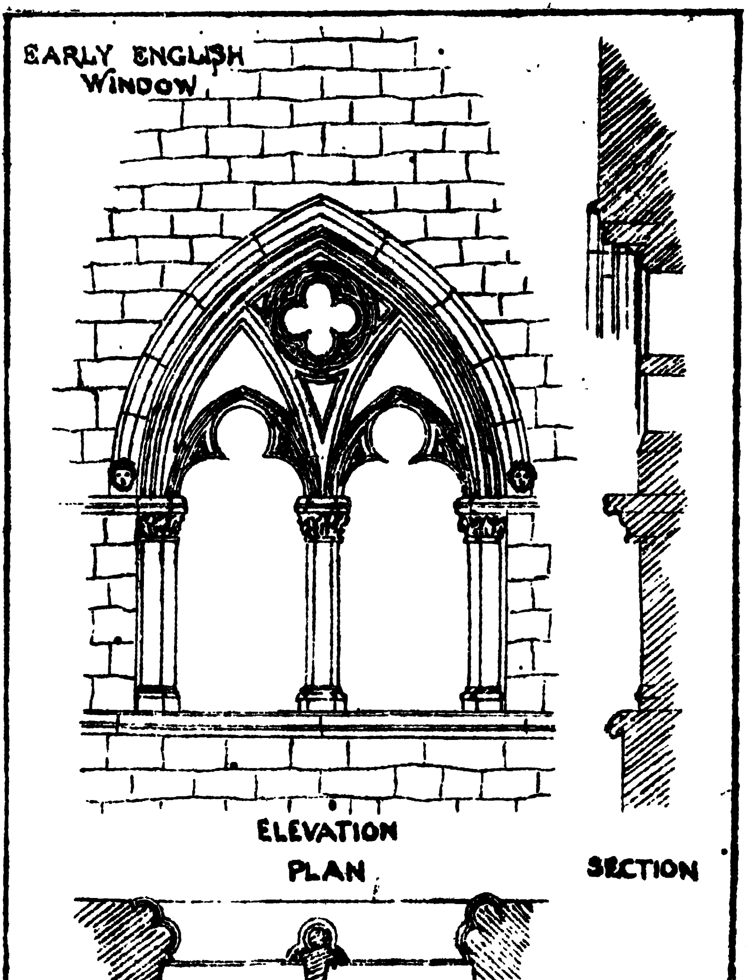

Transverse Section of a window
Inside elevation of a window
Top Rail
Meeting rail
style
Meeting rail
Architrave
Reveal
Shutters
Sash bar
sill
Sur Base
Bottom rail
Elbow
Dado
Back
Base

DETAILS OF DOORS AND WINDOWS

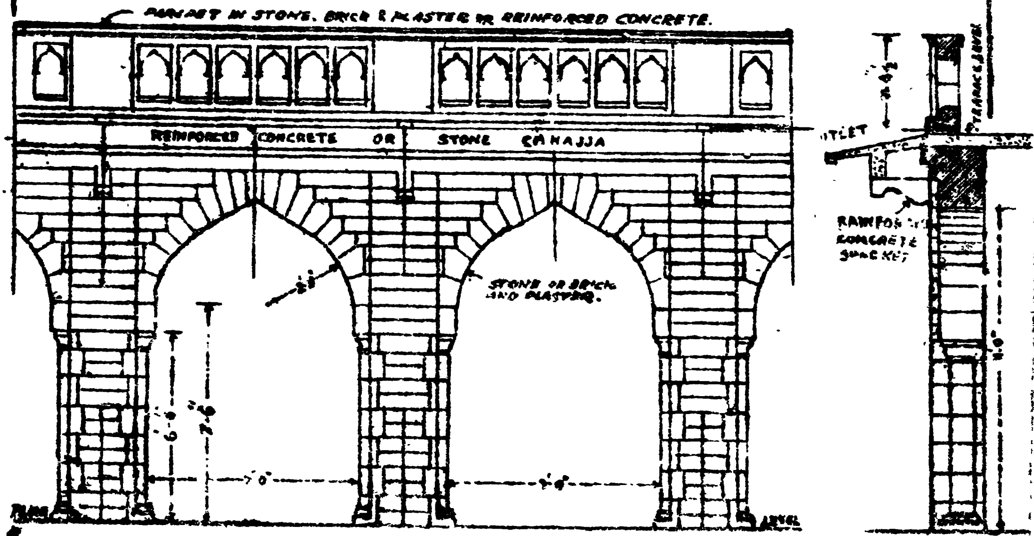



Stone sill.
Wooden sill
Plan of the Window
see fig. 4.R
Sur base
Narrow ground
Fig 5
Plastering
Dado
outside lining
Parting bead
Stop bead.
Inside lining
Fig. 4.
Shutter
Plan of window boxings &c. of Fig 1 to a
Back lining
Architrave
Skirting board
Floor board
Rafter of the Roof
Eaves board
Tie beam
Gutter board
Gutter bearer
Lead or Zinc
Section of a leaded gutter
Flashing


NORMAN WINDOW
Capital of Norman Column
Octagonal Shaft
String at 1.0.
12.0
Circular
12.0
NORMAN NAVE ARCADE
Pattern


EARLY ENGLISH
WINDOW
ELEVATION
PLAN
SECTION

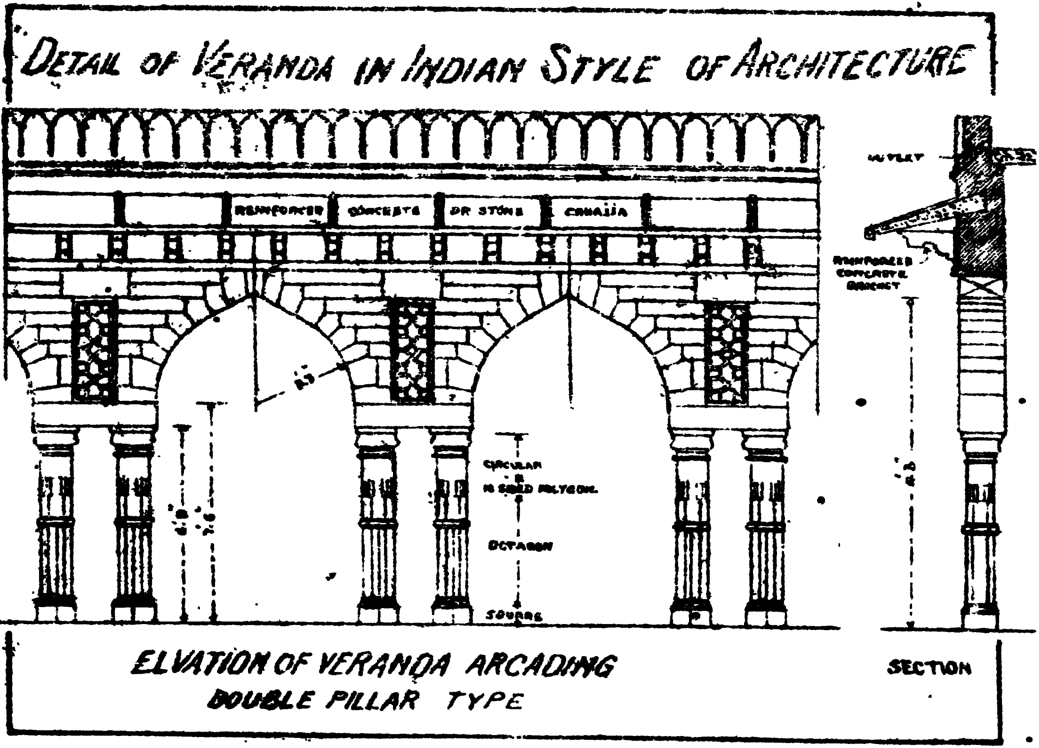
DETAILS OF VERANDA IN INDIAN STYLE OF ARCHITECTURE.

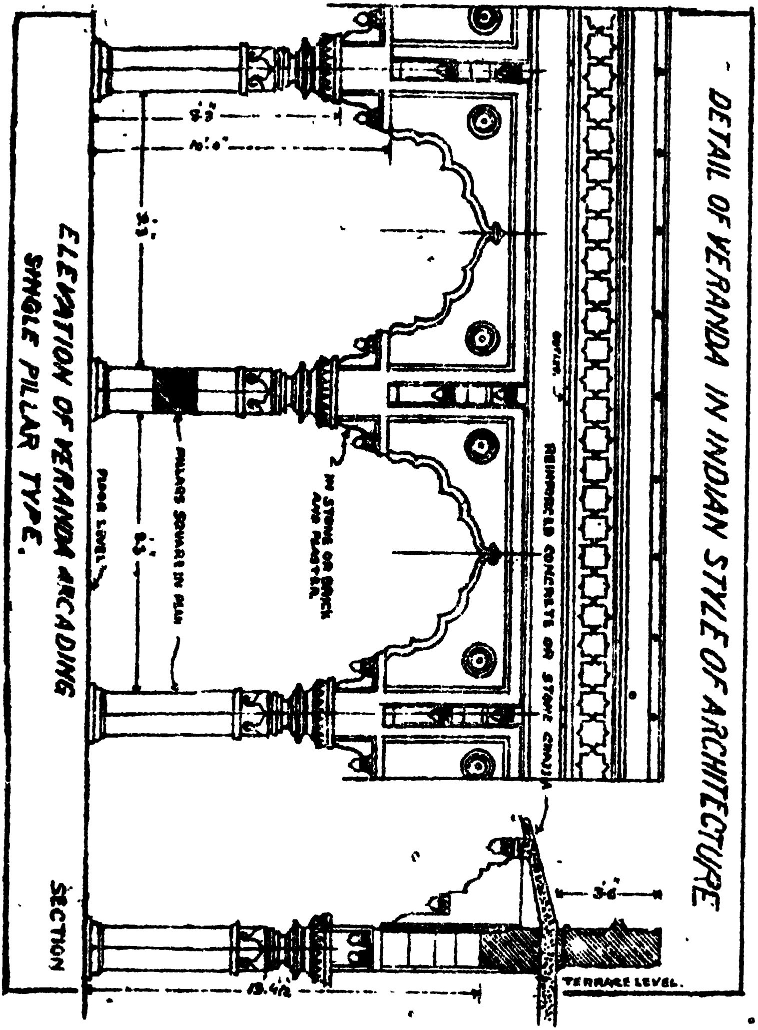


ELEVATION OF VERANDA ARCADING

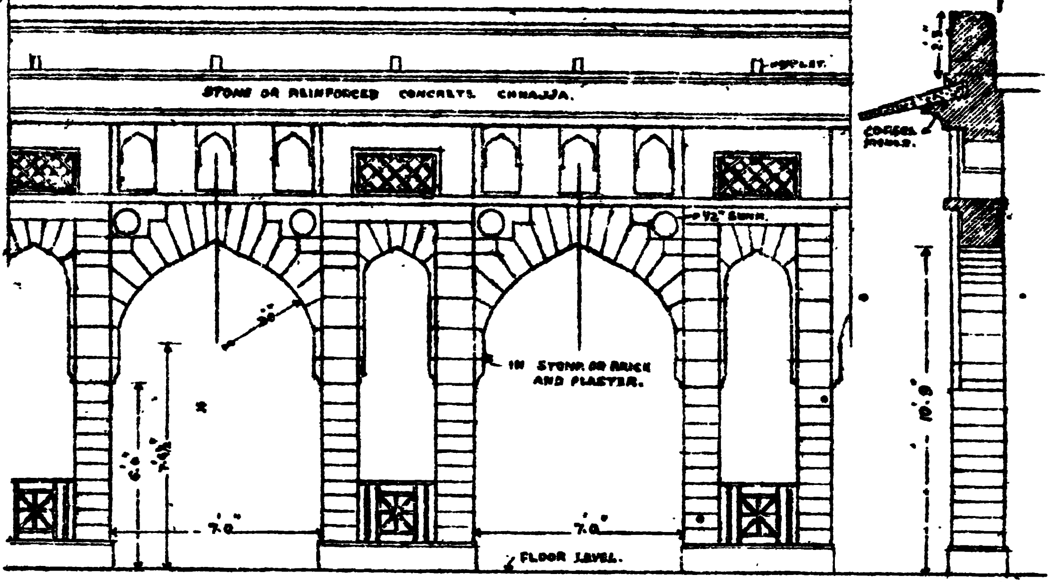
PILLAR AND PILASTER TYPE.

SECTION.


DETAIL OF VERANDA IN INDIAN STYLE OF ARCHITECTURE
REINFORCED CONCRETE OR STONE CHHAJJA
CIRCULAR
16 SIDED POLYGON
OCTAGON
SQUARE
REINFORCED CONCRETE BRACKET
ELVATION OF VERANDA ARCADING
DOUBLE PILLAR TYPE
SECTION

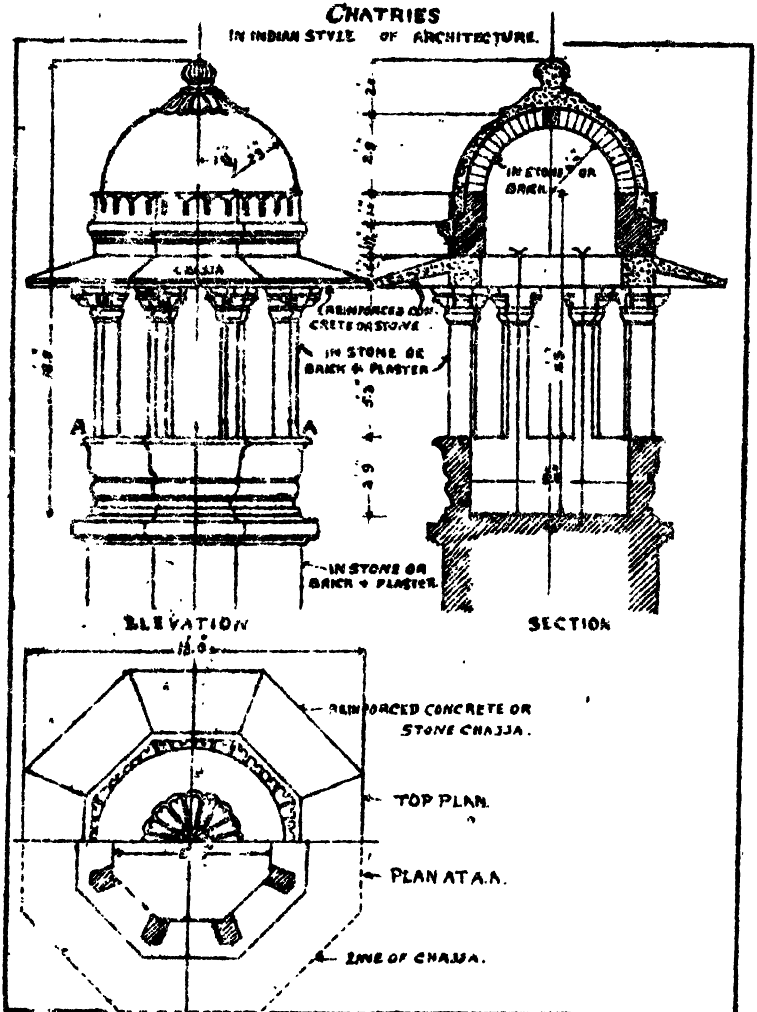

DETAIL OF VERANDA IN INDIAN STYLE OF ARCHITECTURE
ELEVATION OF VERANDA ARCADING
SINGLE PILLAR TYPE.
SECTION
REINFORCED CONCRETE OR STONE CHAJJA
IN STONE OR BRICK AND PLASTER.
PILLARS SQUARE IN PLAN
FLOOR LEVEL
TERRACE LEVEL.
3'-6"

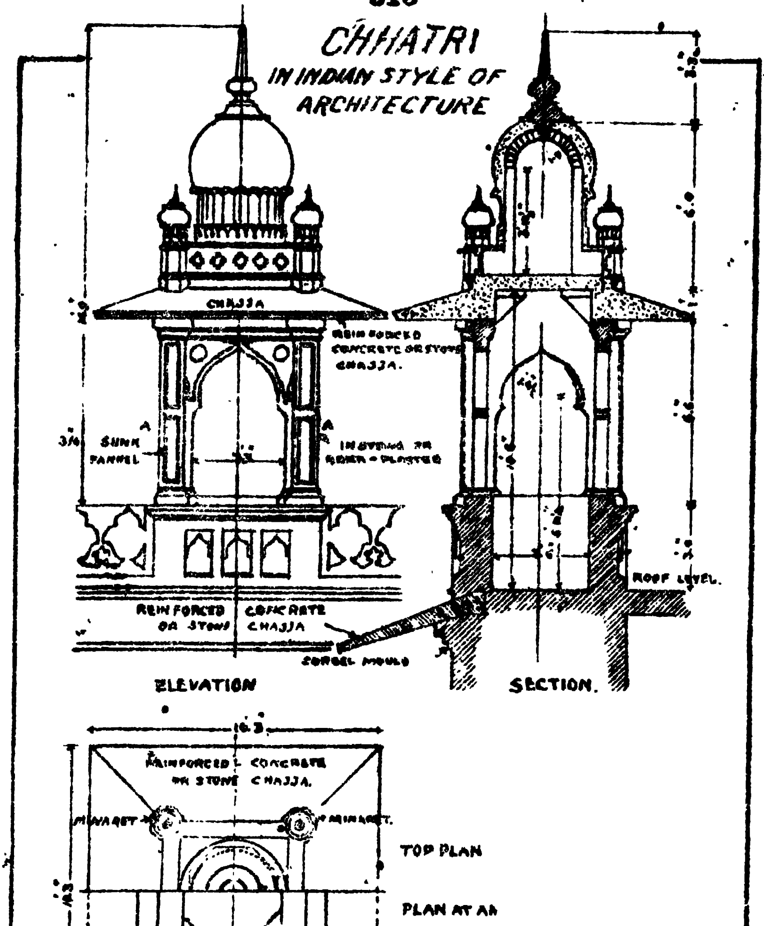
DETAIL OF VERANDA IN INDIAN STYLE OF ARCHITECTURE

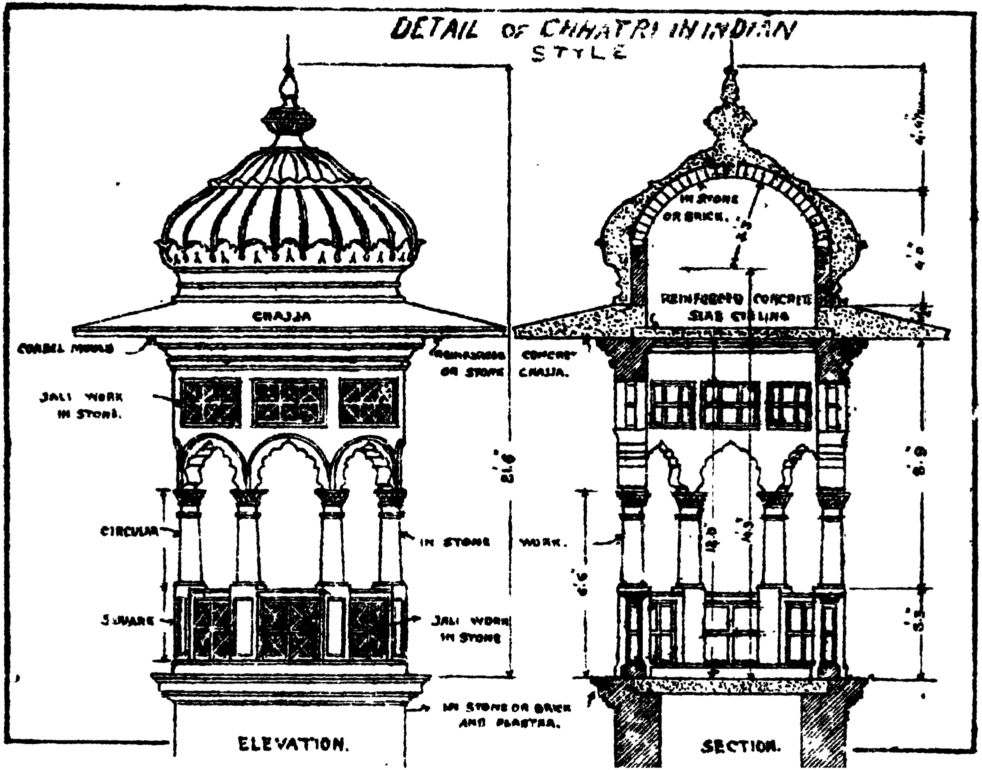


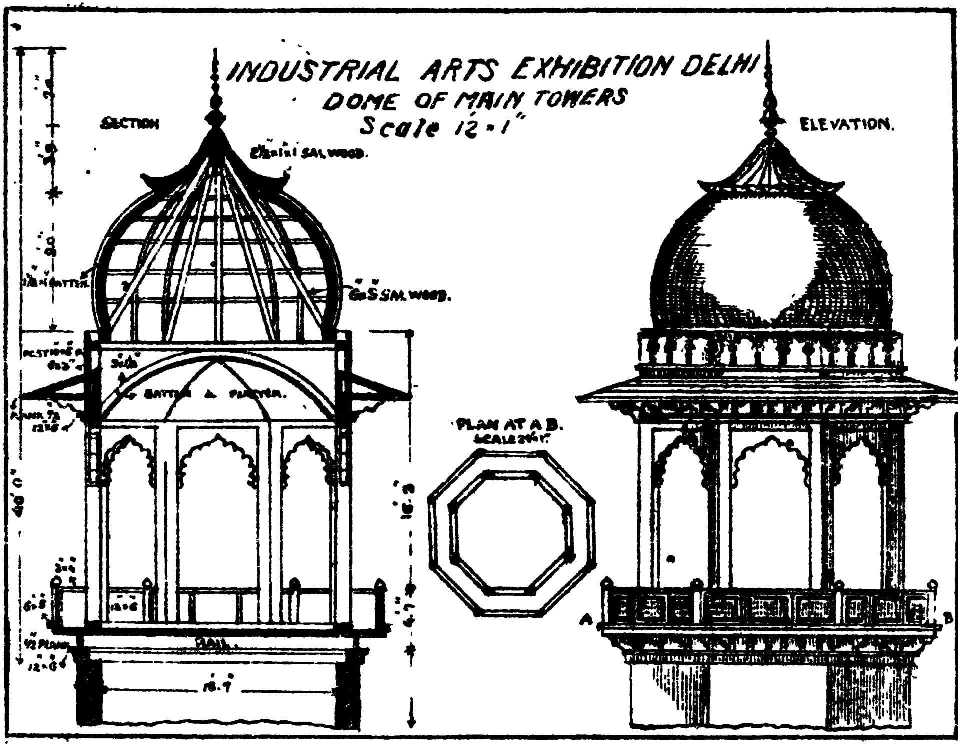
ELEVATION OF VERANDA ARCADING COMBINED PILLAR & ARCH TYPE

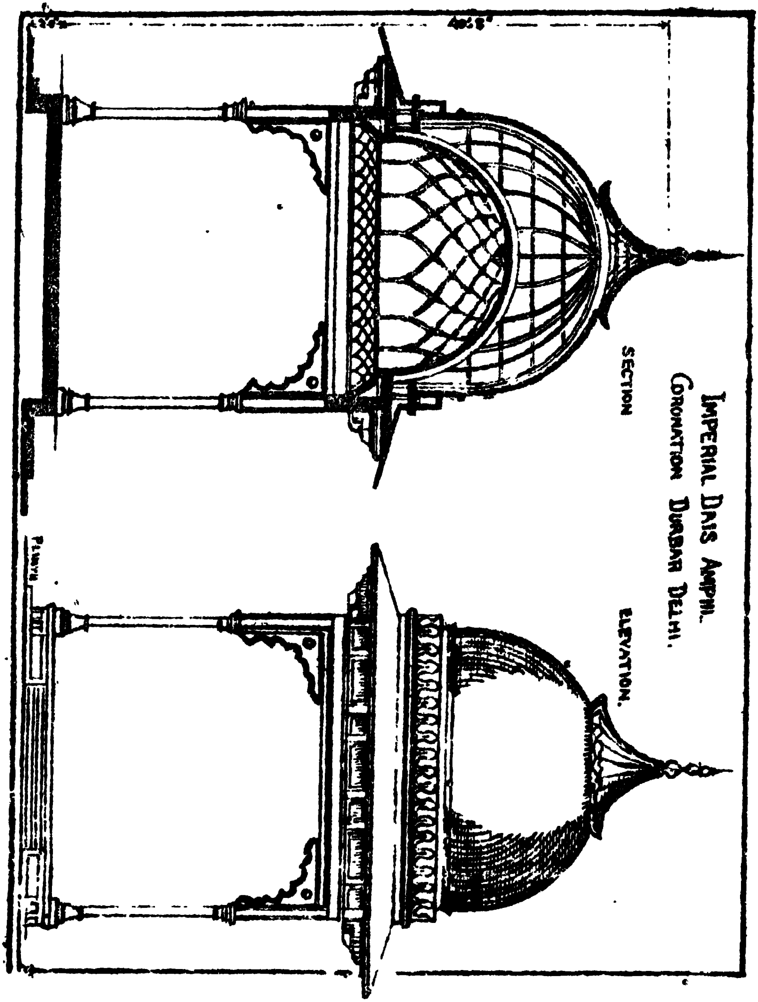
SECTION

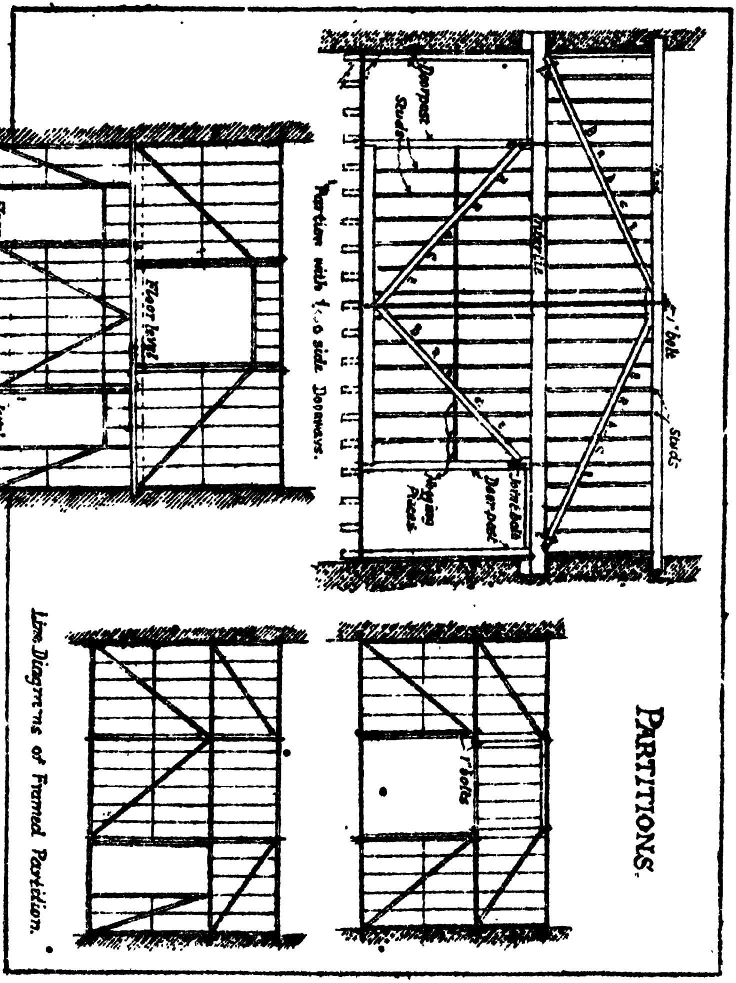

CHATRIES
IN INDIAN STYLE OF ARCHITECTURE.
CHAJJA
IN STONE OR BRICK
REINFORCED CONCRETE OR STONE
IN STONE OR BRICK & PLASTER
IN STONE OR BRICK + PLASTER.
ELEVATION
SECTION
REINFORCED CONCRETE OR STONE CHAJJA.
TOP PLAN.
PLAN AT A.A.
LINE OF CHAJJA.


CHHATRI
IN INDIAN STYLE OF ARCHITECTURE
CHAJJA
REINFORCED CONCRETE OR STONE CHAJJA.
SUNK PANNEL
REINFORCED CONCRETE OR STONE CHAJJA
ROOF LEVEL.
ELEVATION
SECTION.
REINFORCED CONCRETE OR STONE CHAJJA.
MINARET
MINARET.
TOP PLAN
PLAN AT AA
LIMIT OF CHAJJA.


DETAIL OF CHHATRI IN INDIAN STYLE
CHAJJA
CORBEL MOULD
REINFORCED CONCRETE OR STONE CHAJJA.
JALI WORK IN STONE.
CIRCULAR
IN STONE WORK.
SQUARE
JALI WORK IN STONE
IN STONE OR BRICK AND PLASTER.
21'6"
6'6"
ELEVATION.
IN STONE OR BRICK.
REINFORCED CONCRETE SLAB CEILING
4'4"
4'0"
8'9"
3'3"
12'0"
14'3"
SECTION.

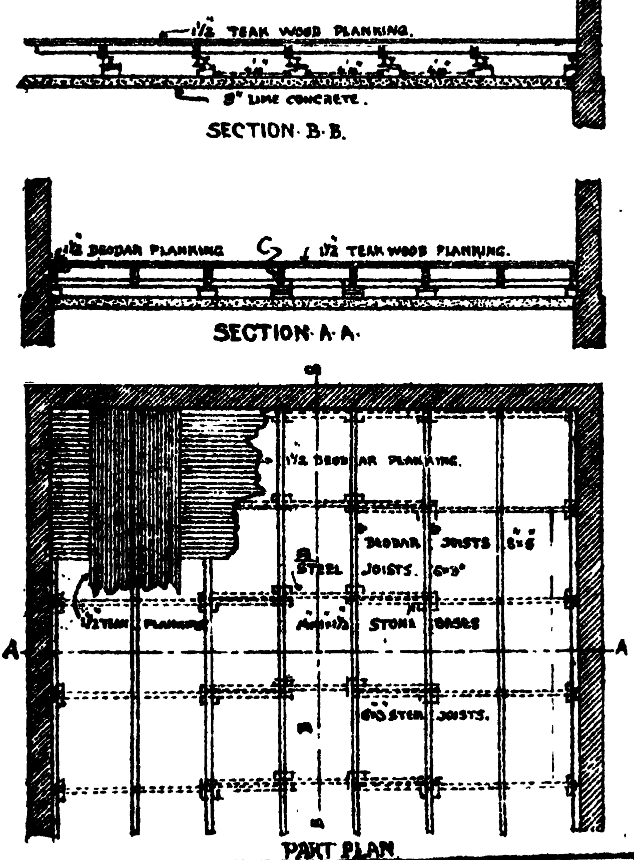

INDUSTRIAL ARTS EXHIBITION DELHI
DOME OF MAIN TOWERS
Scale 12' = 1"
SECTION
ELEVATION.
PLAN AT A B.
SAL WOOD.
BATTEN & PLASTER.
RAIL.
40' 0"
16' 3"
16' 7"
4' 7"
A
B

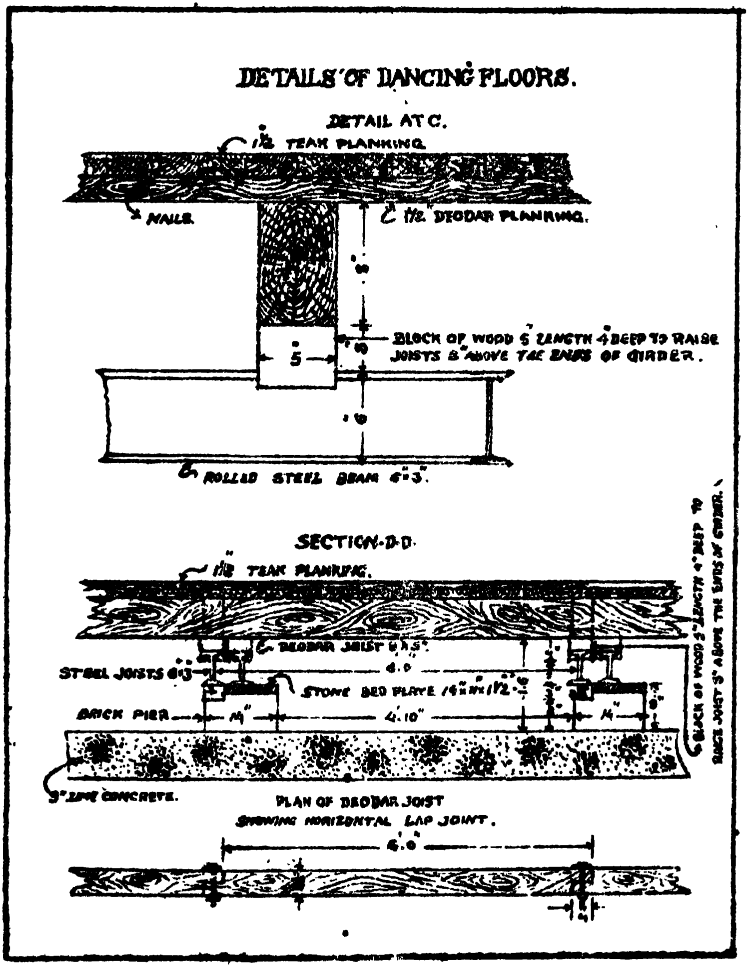

IMPERIAL DAIS AMPHI.
CORONATION DURBAR DELHI.
SECTION
ELEVATION.

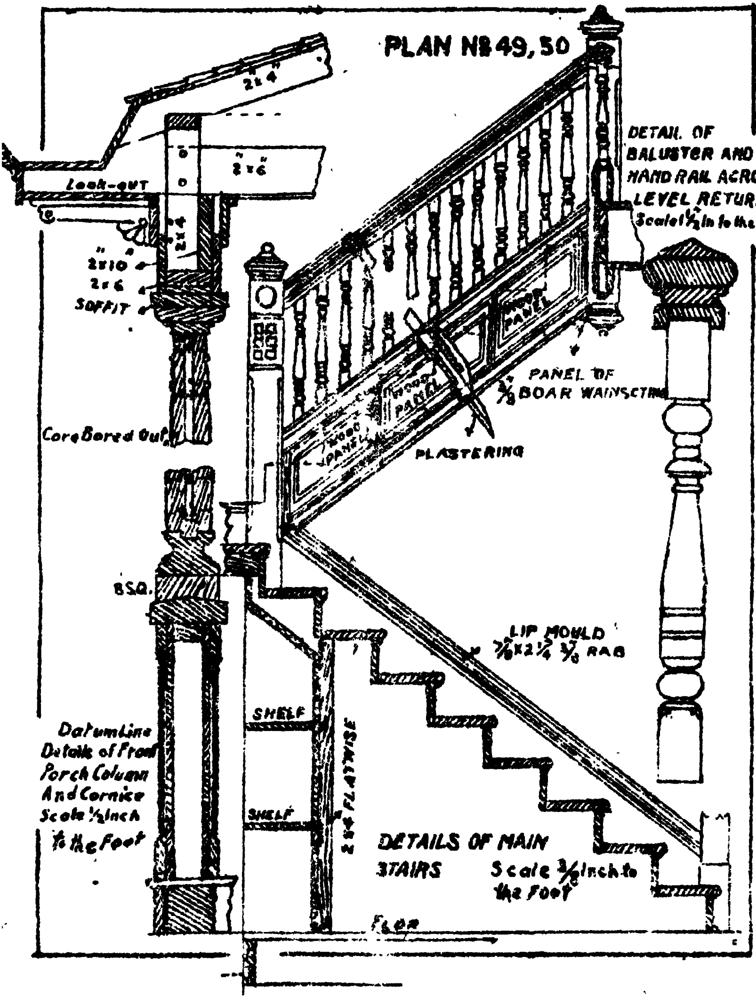

PARTITIONS.
Partition with two side Doorways.
Studs
Door post
Hanging Pieces
Two-Story Framed Partition.
Floor level
Floor level
Line Diagrams of Framed Partition.

DESIGN FOR CANTILEVER DANCING FLOOR

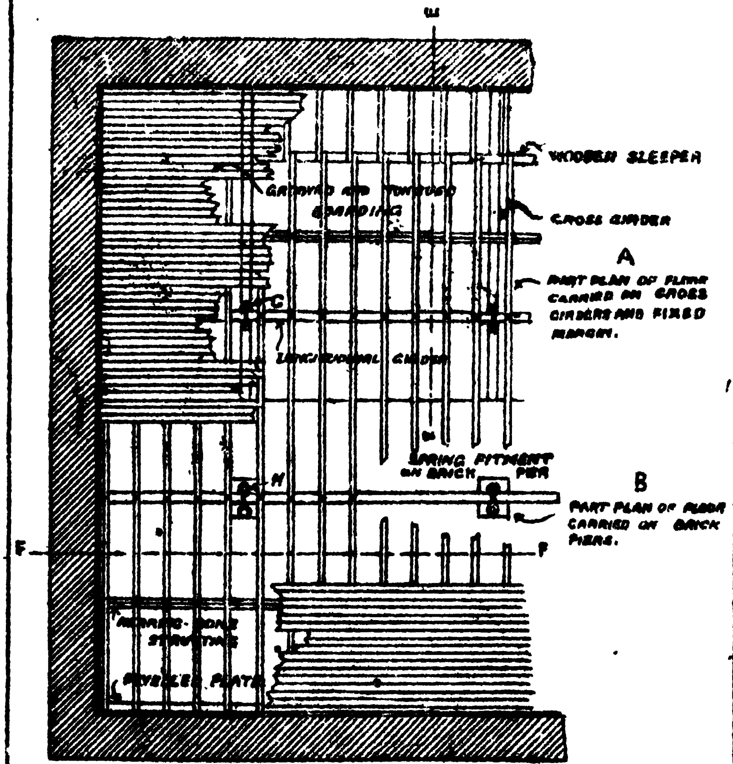
AS CONSTRUCTED AT THOMPSON COLLEGE ROORKEE. (U.P.)




DETAILS OF DANCING FLOORS.
DETAIL AT C.
TEAK PLANKING
NAILS
DEODAR PLANKING.
BLOCK OF WOOD
JOISTS ABOVE THE ENDS OF GIRDER.
ROLLED STEEL BEAM
SECTION D.D.
TEAK PLANKING.
DEODAR JOIST
STEEL JOISTS
STONE BED PLATE
BRICK PIER
LIME CONCRETE.
PLAN OF DEODAR JOIST
SHOWING HORIZONTAL LAP JOINT.

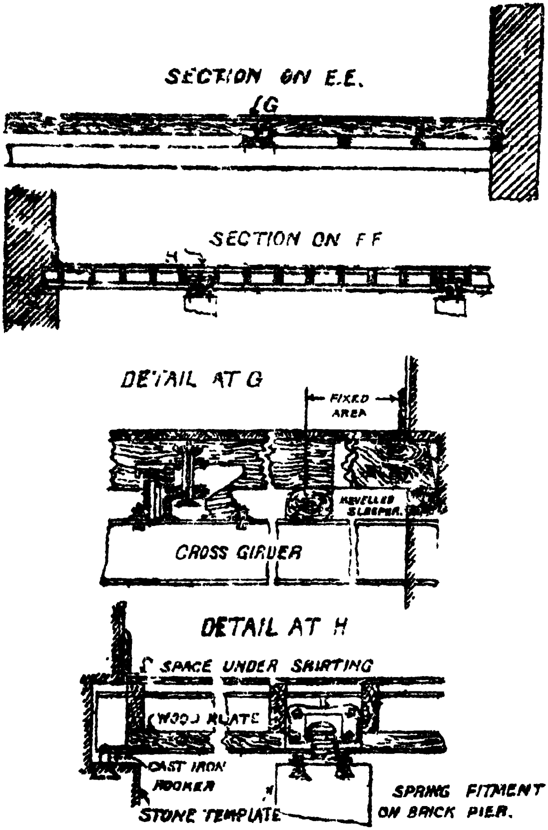

PLAN No 49, 50
2x4
2x6
Look-out
2x10
2x6
SOFFIT
Core Bored Out
8 SQ.
Datum Line
Details of Front
Porch Column
And Cornice
Scale ½ inch
to the Foot
DETAIL OF
BALUSTER AND
HAND RAIL ACROSS
LEVEL RETURN
Scale 1½ In to the Ft
WOOD PANEL
PANEL OF
⅞ BOAR WAINSCTING
PLASTERING
LIP MOULD
⅞x2¼ ⅞ RAB
SHELF
SHELF
2x4 FLATWISE
DETAILS OF MAIN
STAIRS
Scale ½ Inch to
the Foot
FLOR

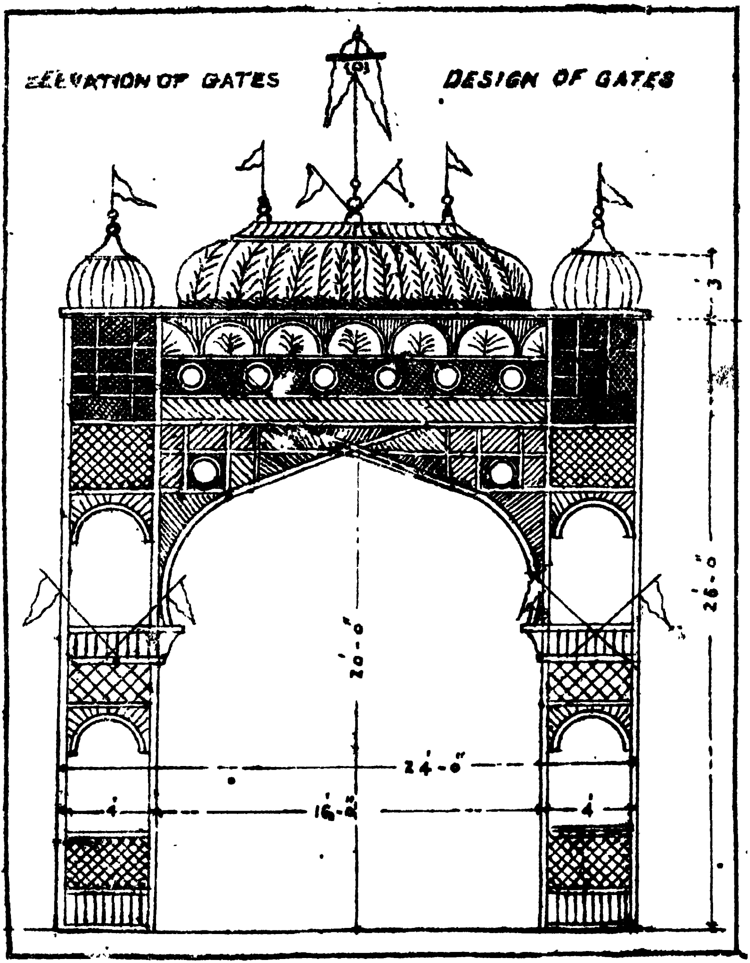
SPRUNG DANCING FLOOR.

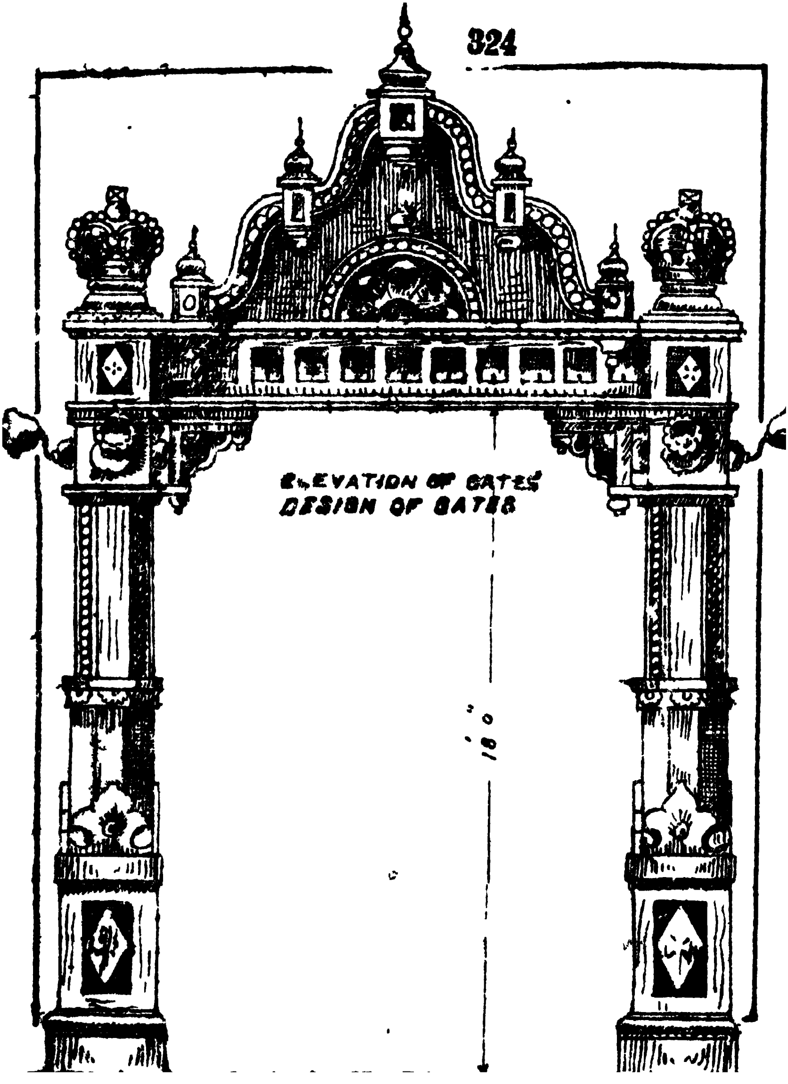


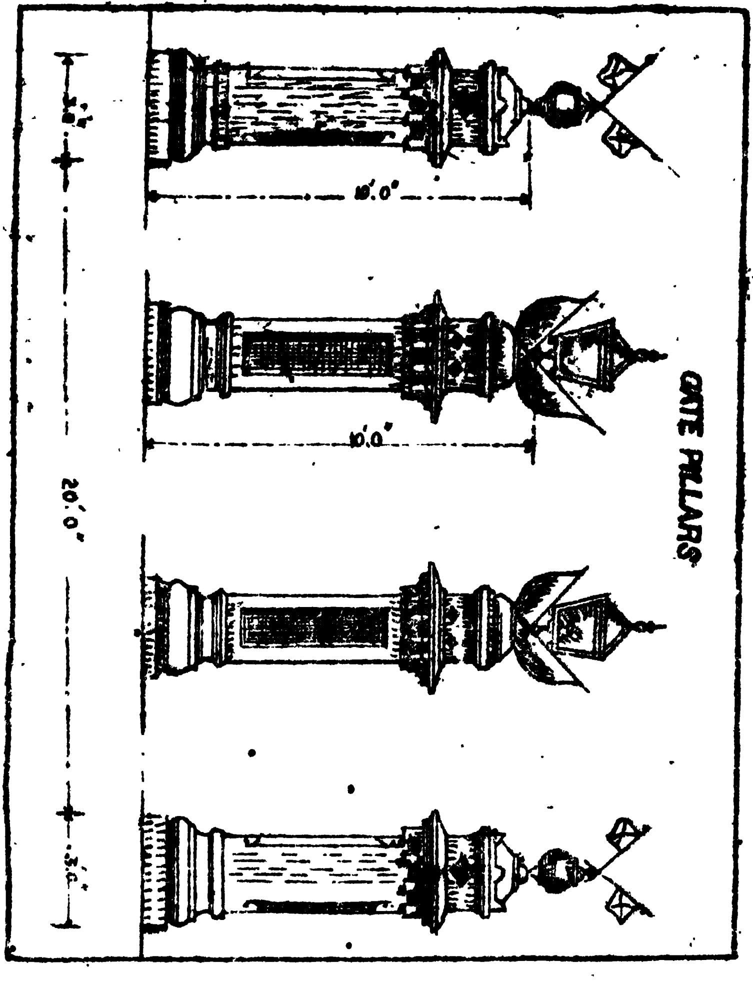
SCALE 1/6" = 1'

DETAILS OF SPRUNG DANCING FLOOR.

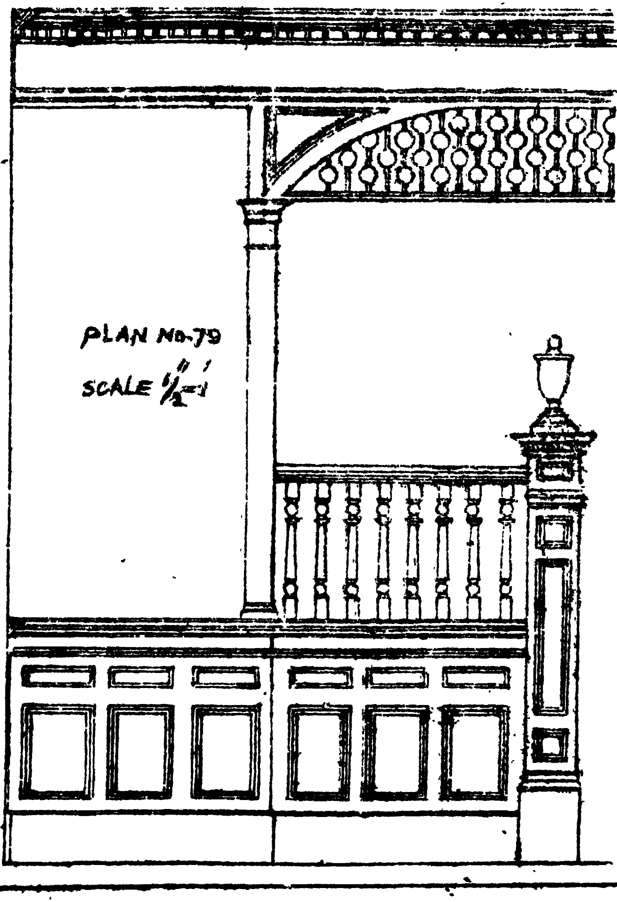



ELEVATION OF GATES
DESIGN OF GATES
3'
26'-0"
20'-0"
24'-0"
4'
16'-0"
4'

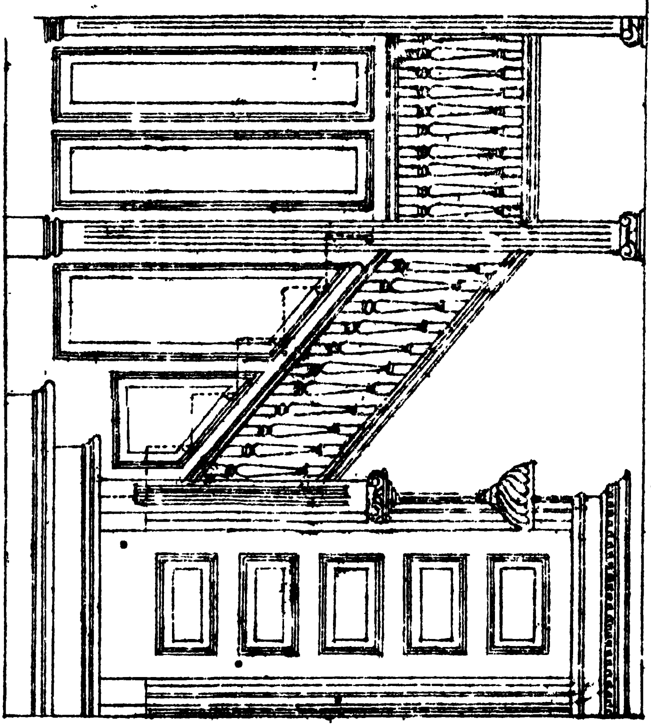

ELEVATION OF GATES
DESIGN OF GATES


GATE PILLARS
10'.0"
10'.0"
20'.0"
3'.6"
3'.6"

DETAILS OF NEWEL POST, GRILLE & PANEL WORK.

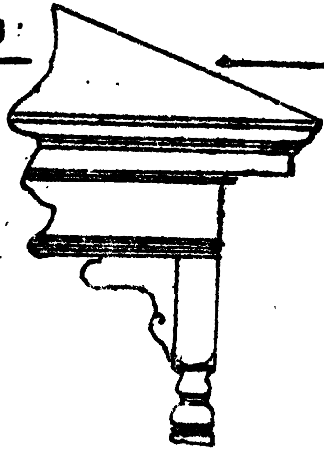


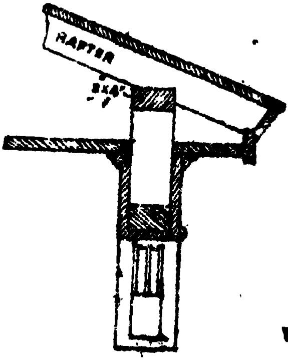
PLAN No. 81



ELEVATION OF STAIRS SHOWING TRIM. SCALE 3/8" = 1'

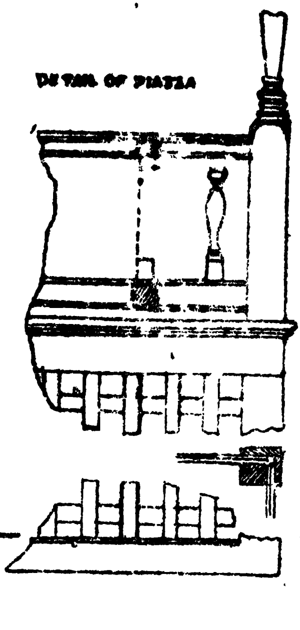
DIFFERENT DETAILS





DETAIL OF PIAZZA CORNICE

DETAIL OF PIAZZA



SCALE 1/2" = 1'

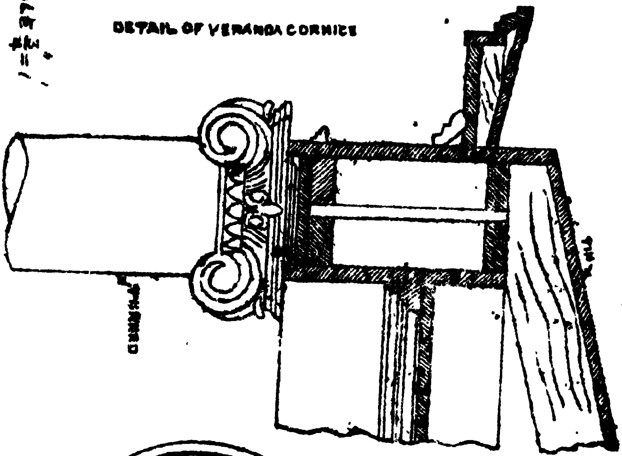
PLAN No. 73

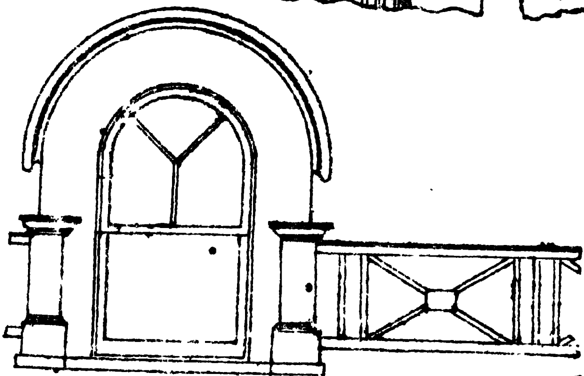
PLAN No. 81

DIFFERENT DETAILS

DETAIL OF VERANDA CORNICE

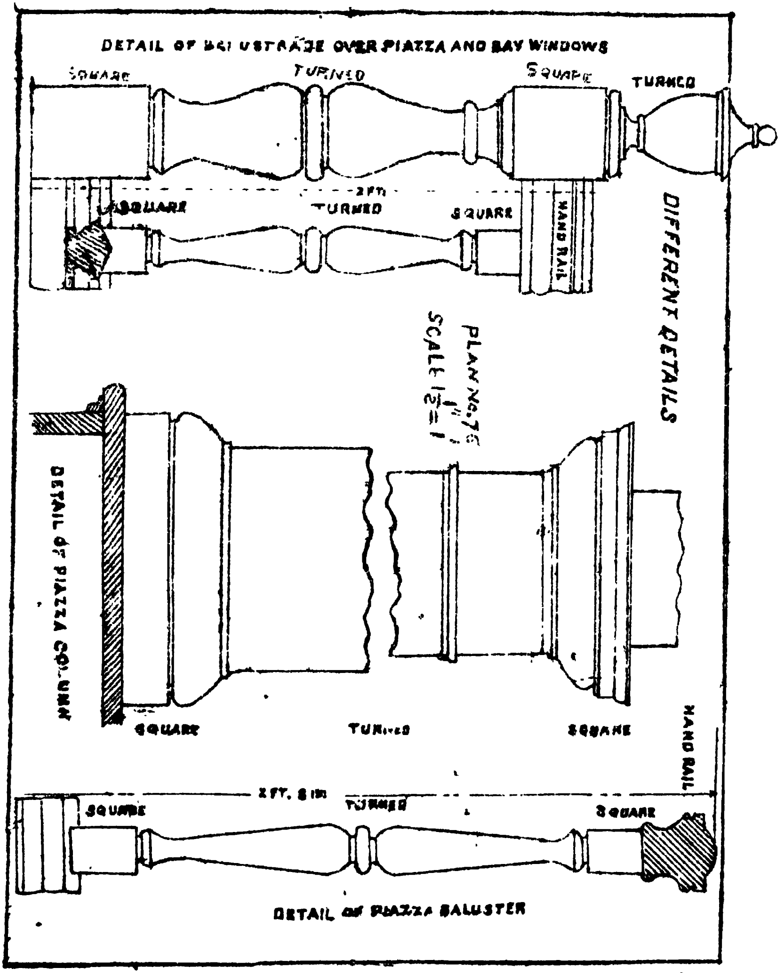
SCALE 3/4 = 1'





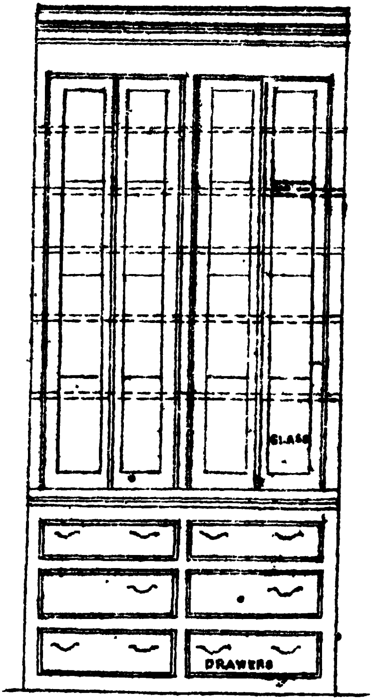
DETAIL OF DORMER WINDOWS AND BALUSTRADE

SCALE 1/8 = 1'

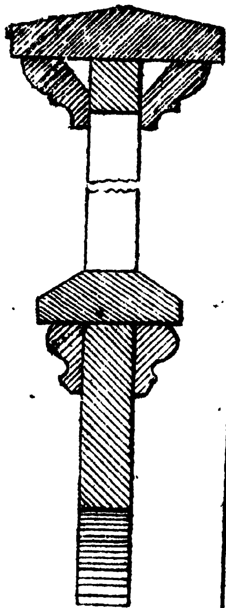

DETAIL OF BALUSTRADE OVER PIAZZA AND BAY WINDOWS
SQUARE
TURNED
SQUARE
TURNED
2 FT.
SQUARE
TURNED
SQUARE
HAND RAIL
DIFFERENT DETAILS
PLAN No. 75
SCALE 1/2" = 1'
DETAIL OF PIAZZA COLUMN
SQUARE
TURNED
SQUARE
HAND RAIL
2 FT. 8 IN.
SQUARE
TURNED
SQUARE
DETAIL OF PIAZZA BALUSTER

DIFFERENT DETAILS

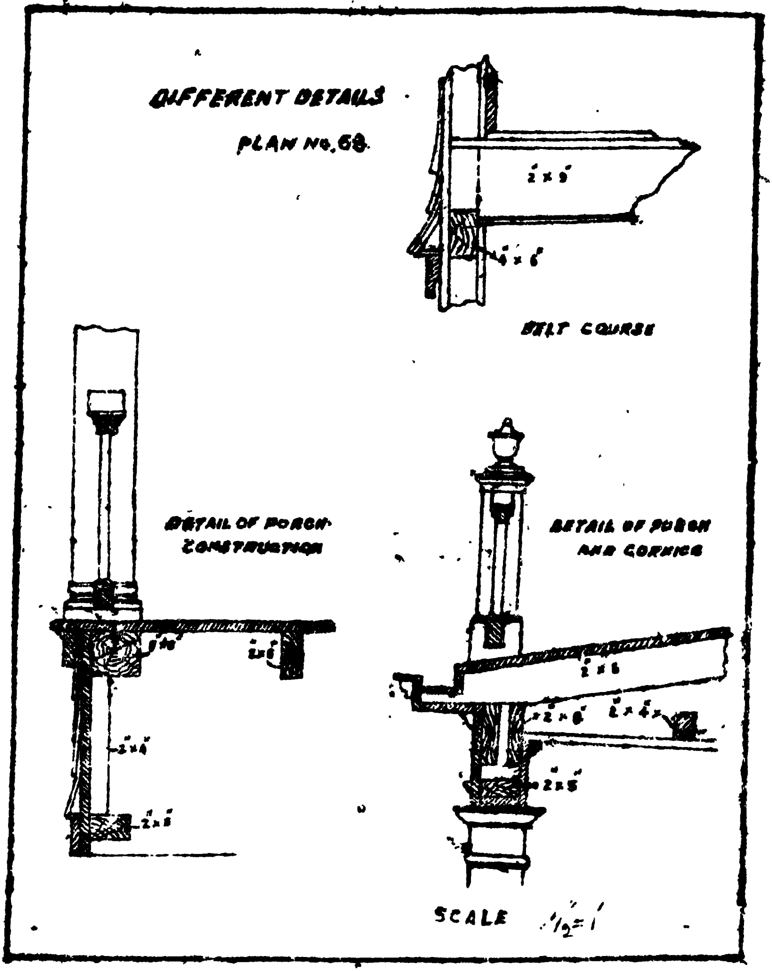
PLAN No. 72



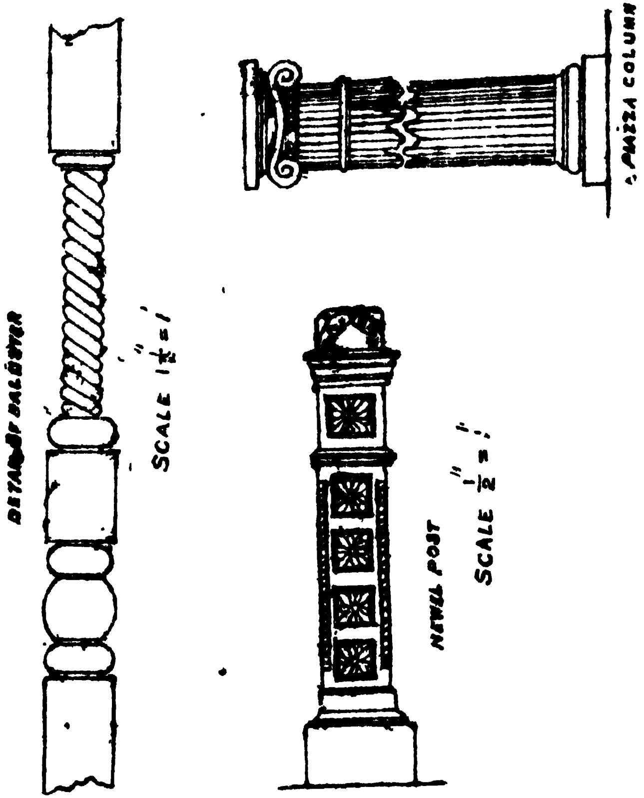
ELEVATION
OF
DRESSER IN PANTRY
SCALE 3/8" = 1'



CROSS SECTION
OF
PORCH RAIL
SCALE 3" = 1'


DIFFERENT DETAILS
PLAN No. 68
BELT COURSE
DETAIL OF PORCH CONSTRUCTION
DETAIL OF PORCH AND CORNICE
SCALE 1/2"=1'

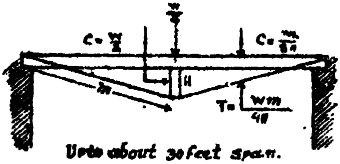
DIFFERENT DETAILS



PLAN No. 66

BUILT BEAMS AND TRUSSES.

DETAILES OF UNDER TRUSSED BEAMS.

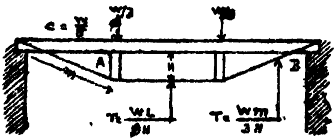


Up to about 30 feet span.

For m $bd^2 = \frac{WL}{8m}$.

$bd^3 = \frac{WL^2}{768}$.

$m = \sqrt{\frac{L^2}{4} + H^2}$



Up to about 40 feet span.

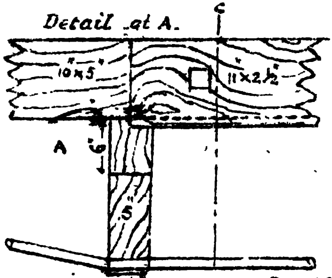
For m $bd^2 = \frac{WL}{12m}$.

$bd^3 = \frac{WL^2}{340}$

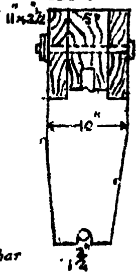
$m = \sqrt{\frac{L^2}{9} + H^2}$

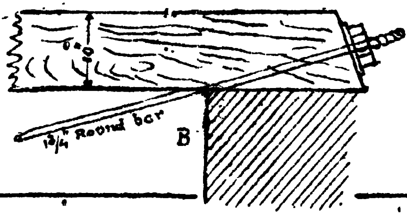
$H = \frac{L}{8}$ to $\frac{L}{12}$.

Detail at A.

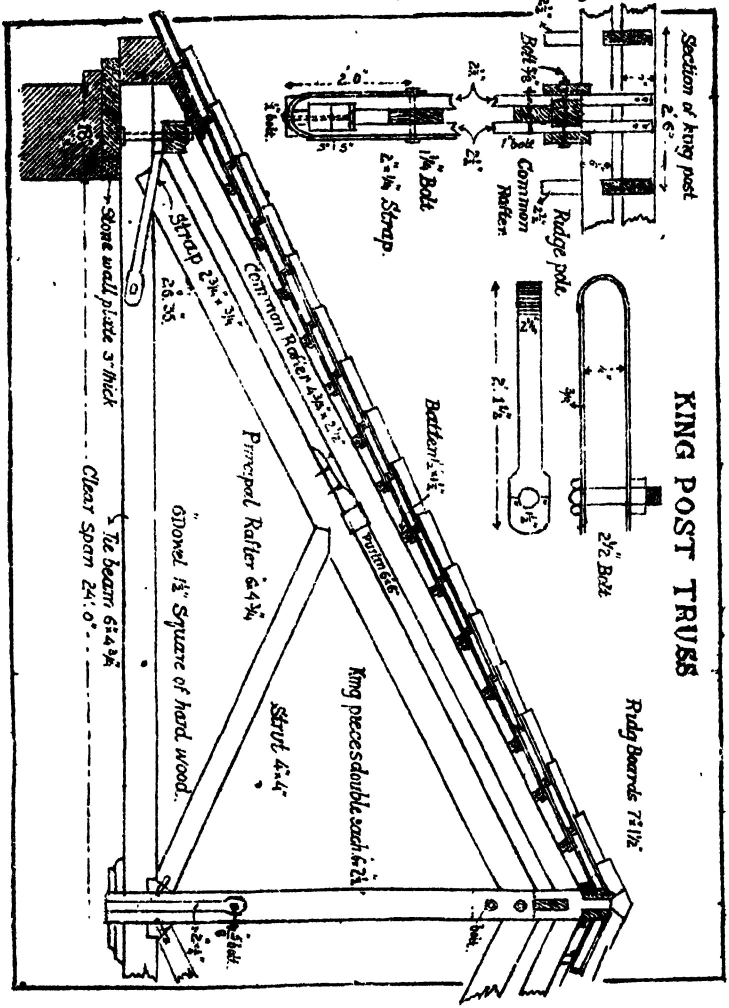


Section on CD.



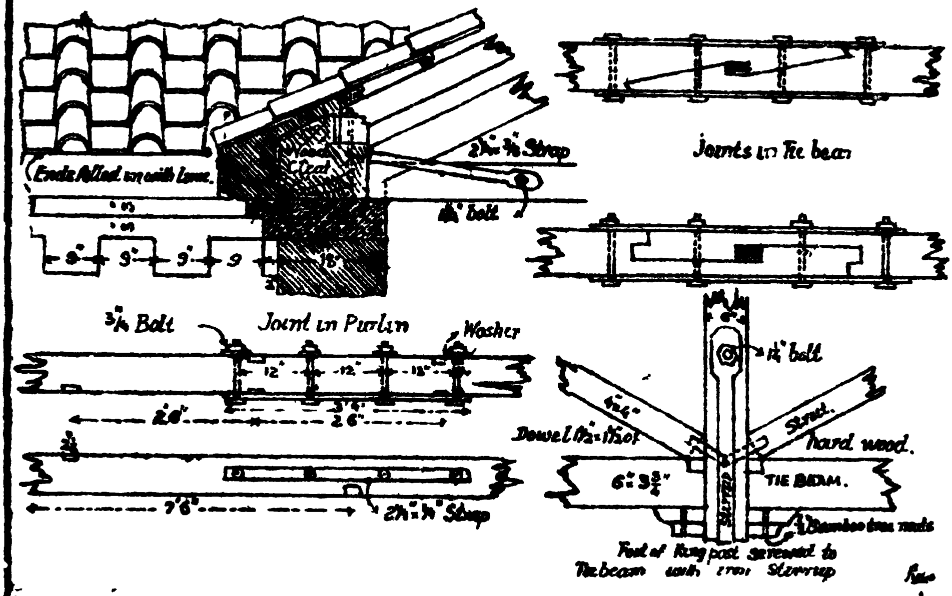


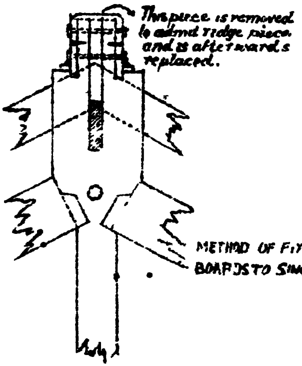
Detail at B.

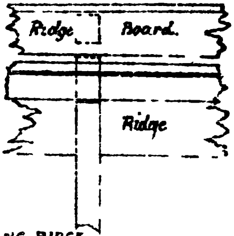

KING POST TRUSS
Section of king post
Ridge boards 7"x1½"
Bolt ⅝"
1" bolt
Common Rafter
Ridge pole
2'.0"
1¼" Bolt
2"x¼" Strap.
2'.1⅛"
Batten 1½"x1½"
2½" Bolt
Strap
Strap 2¾"x⅜"
Common Rafter 4⅜"x2½"
Stone wall plate 3" thick
Principal Rafter 6"x4¾"
Dowel 1½" Square of hard wood.
Purlin 6"x6"
Tie beam 6"x4¾"
Clear span 24'.0"
Strut 4"x4"
King piece double each 6"x2¼"
Ridge Boards 7"x1½"
bolt.
⅝" bolt.

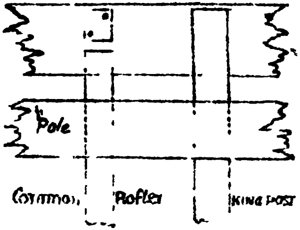
DETAILS OF KING POST TRUSS.

Scale 2½" = 1'

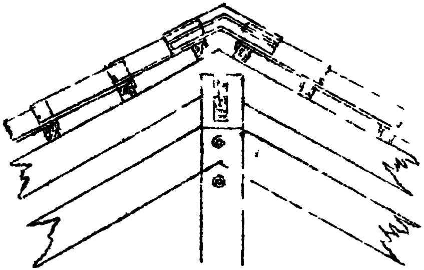




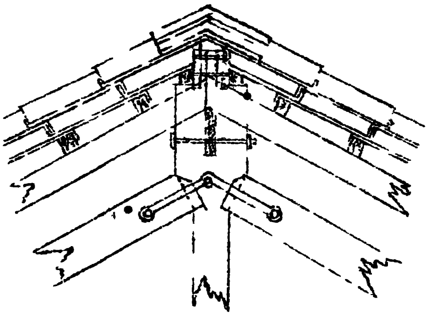




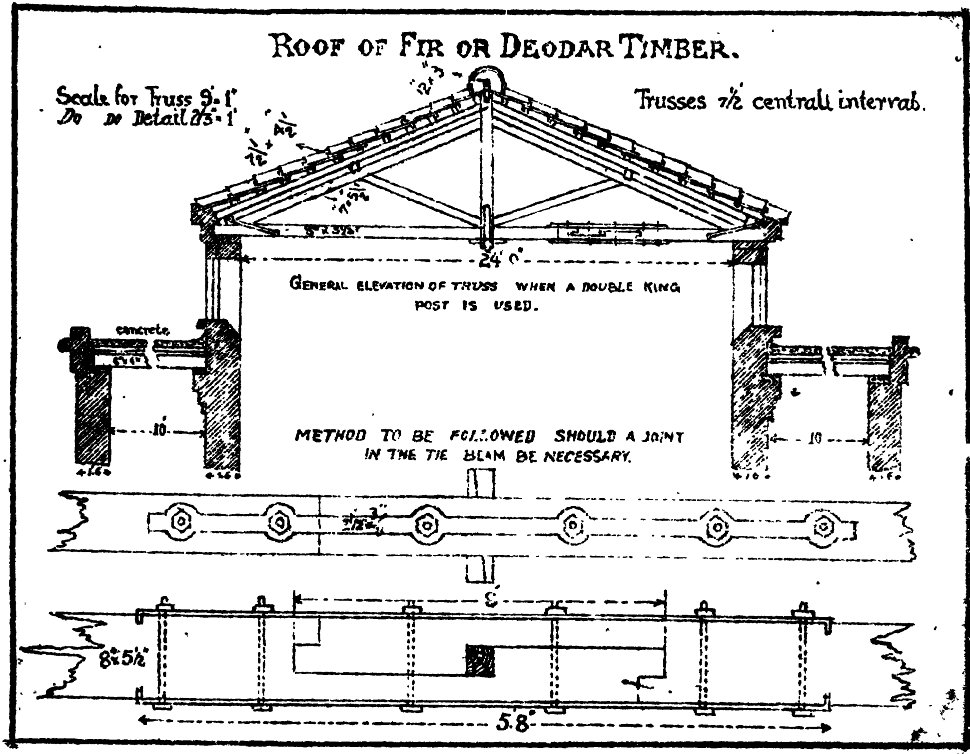
METHOD OF FITTING RIDGE BOARDS TO SINGLE KING POST

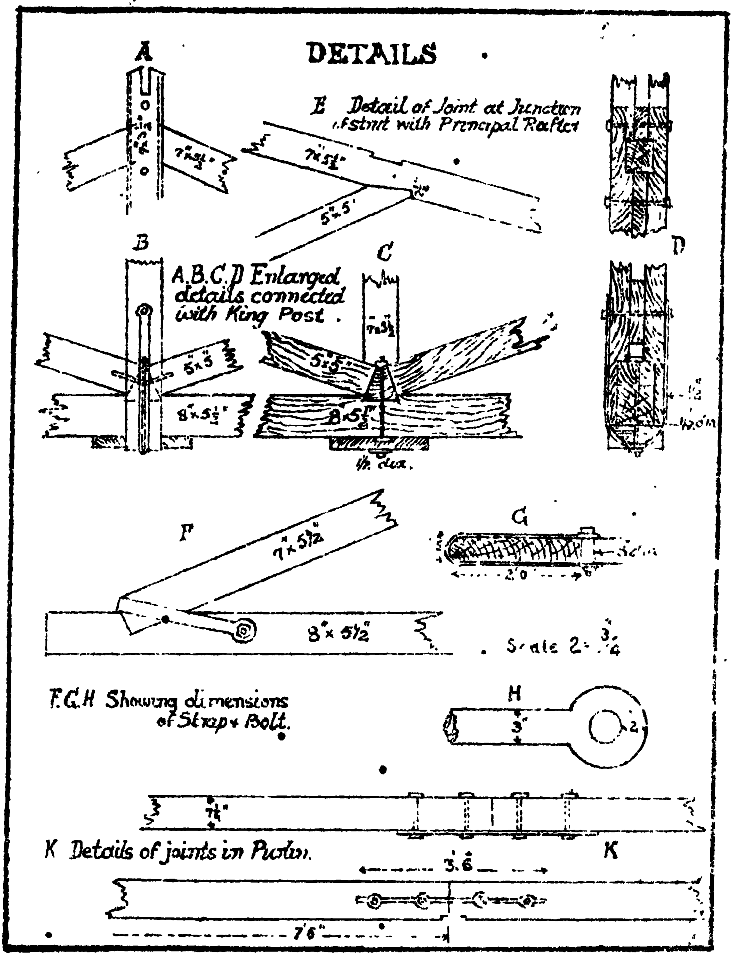


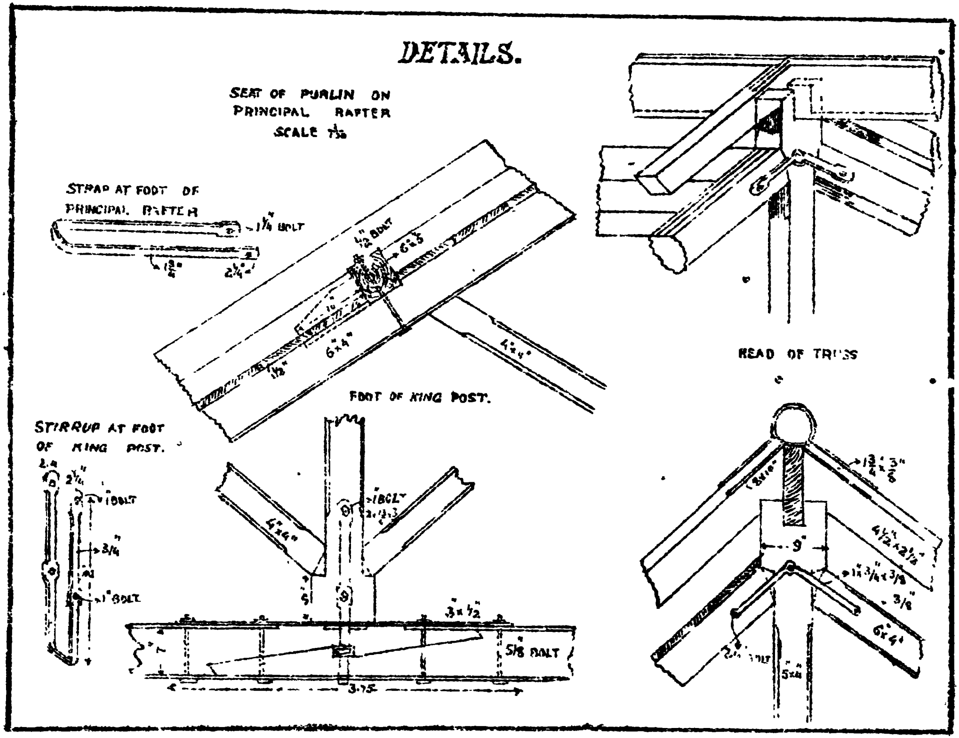
SINGLE ALLAHABAD TILING WITH DOUBLE KING POST

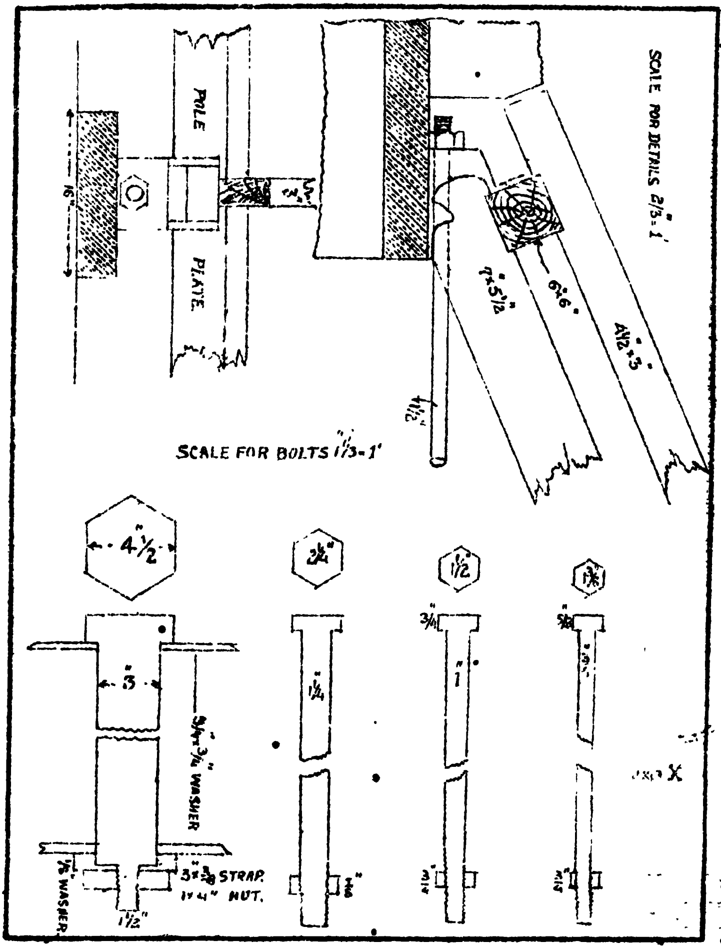


DOUBLE ALLABAD TILING WITH SINGLE KING POST


ROOF OF FIR OR DEODAR TIMBER.
Scale for Truss 9'=1"
Do do Detail 2½'=1'
Trusses 7½' central intervals.
concrete
24' 0"
GENERAL ELEVATION OF TRUSS WHEN A DOUBLE KING POST IS USED.
10'
10
METHOD TO BE FOLLOWED SHOULD A JOINT IN THE TIE BEAM BE NECESSARY.
3"
8"×5½"
5.8"

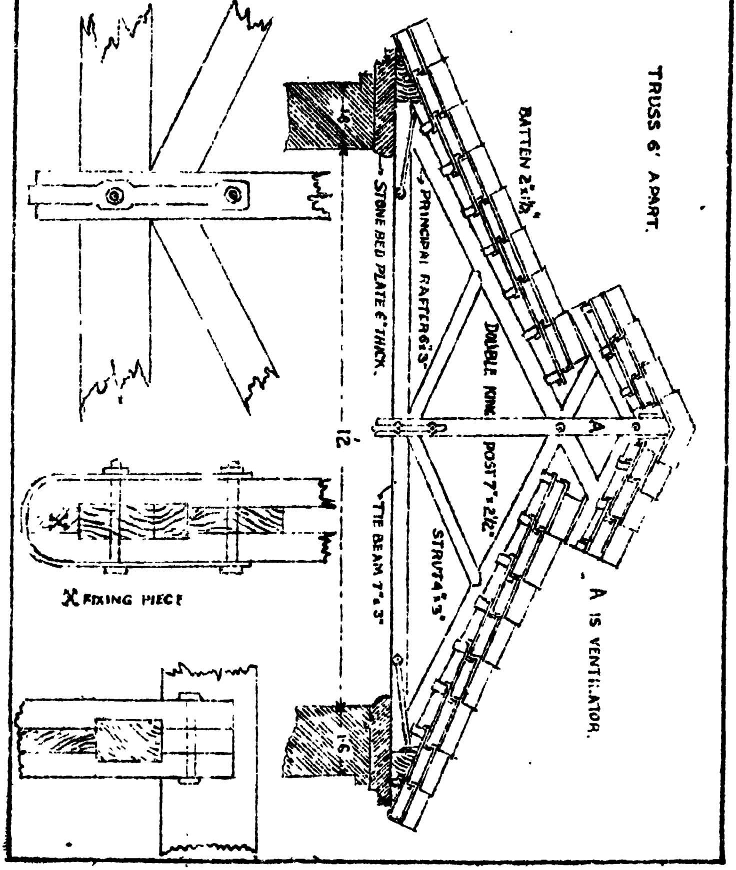

DETAILS
A
E Detail of Joint at Junction of strut with Principal Rafter
B
C
D
A.B.C.D Enlarged details connected with King Post.
F
G
Scale 2 = 3/4
H
F.G.H Showing dimensions of Strap & Bolt.
K Details of joints in Purlin.
K

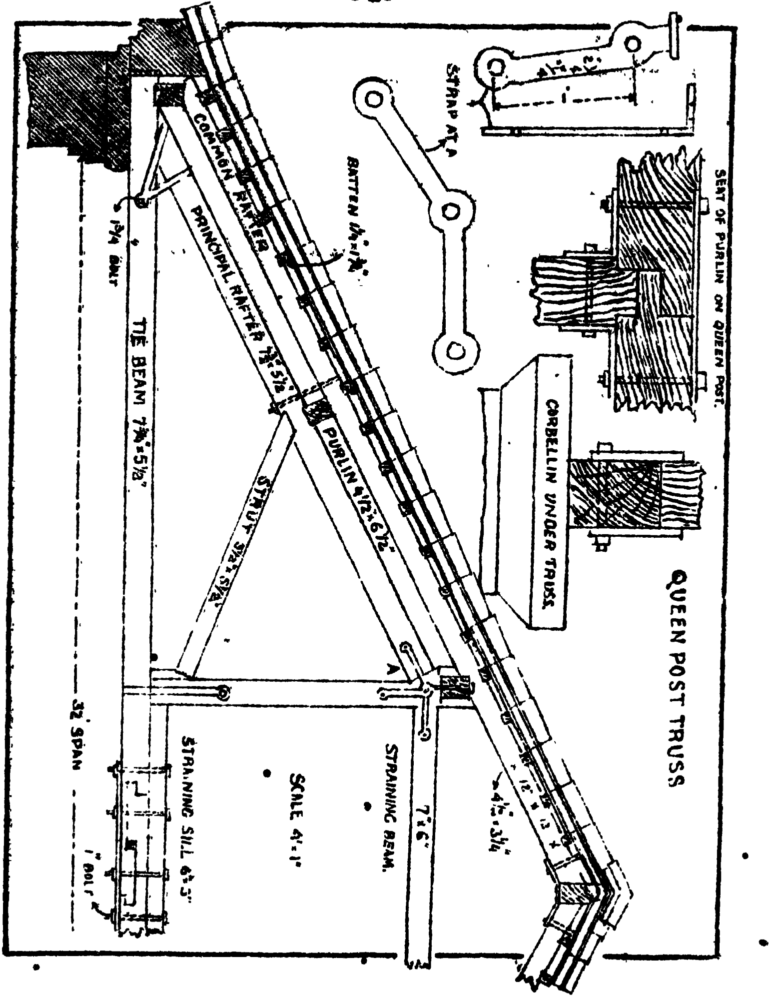

DETAILS.
SEAT OF PURLIN ON PRINCIPAL RAFTER SCALE 1/16
STRAP AT FOOT OF PRINCIPAL RAFTER
1¼" BOLT
½" BOLT
6"x3"
6"x4"
4"x4"
HEAD OF TRUSS
FOOT OF KING POST.
STIRRUP AT FOOT OF KING POST.
4"x4"
3"x½"
5/8 BOLT
3.75
1¾"x3/8"
4½"x2½"
9"
3/8
6"x4"
5x4


SCALE FOR DETAILS 2/3"=1'
POLE
PLATE
16"
7"x5½"
6"x6"
4½"x3"
1½"
SCALE FOR BOLTS 1/3"=1'
4½"
3"
2¼"
1½"
1⅜"
1¼"
1"
3/4"
5/8"
3/4" x 3/16" WASHER
3 x 3/8 STRAP
1½" NUT
1½"
⅝" WASHER

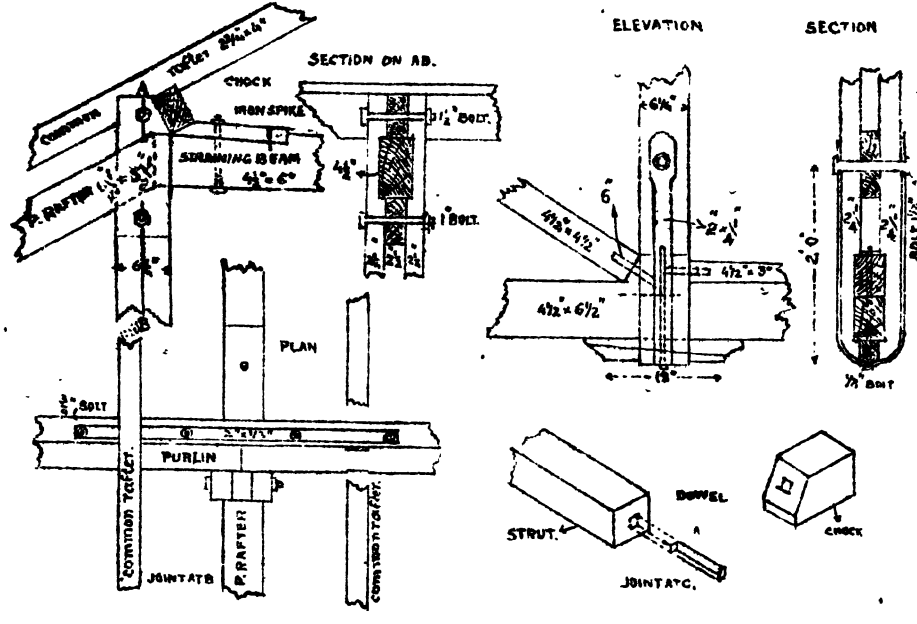
DOUBLE KING POST TRUSS WITH VENTILATOR

SCALE FOR TRUSS 4' = 1" & FOR DETAILS 1' = 1".




QUEEN POST TRUSS
SEAT OF PURLIN ON QUEEN POST.
STRAP AT A
CORBELLIN UNDER TRUSS.
COMMON RAFTER
PRINCIPAL RAFTER 7½"×5½"
PURLIN 4½"×6½"
STRUT 5½"×5½"
TIE BEAM 7⅞"×5½"
A
STRAINING BEAM.
7"×6"
4½"×3¼"
SCALE 4'=1"
STRAINING SILL 6"×3"
1" BOLT
32' SPAN

DETAIL OF QUEEN POST TRUSS



MATHEMATICAL TREATMENT (Stresses)

P. RAFTER = $C = 3/8\,W \operatorname{cosec}\theta + 1/4\,W \operatorname{cosec}\theta$.

T. BEAM. = $T = 3/8\,W \cot\theta + 1/4\,C \cot\theta$.

K. POST = $T = 1/4\,W + 1/2\,W_1$.

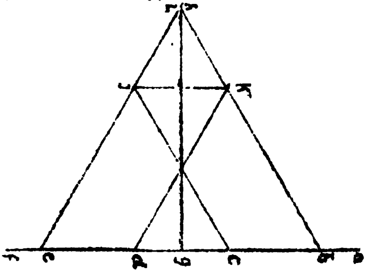
STRUT = $C = 1/8\,W \operatorname{cosec}\theta$.

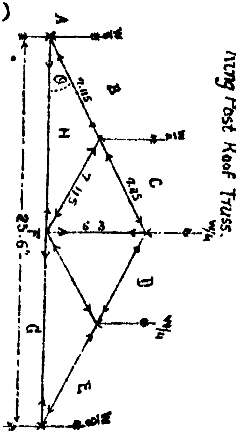
C = COMPRESSIVE STRESS

T = TENSILE STRESS.

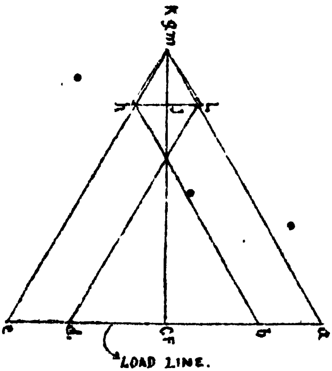
W = TOTAL WEIGHT ON ROOF.

W_1 = WEIGHT OF TRUSS.



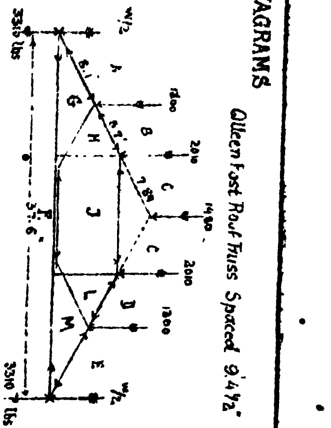


STRESS DIAGRAMS

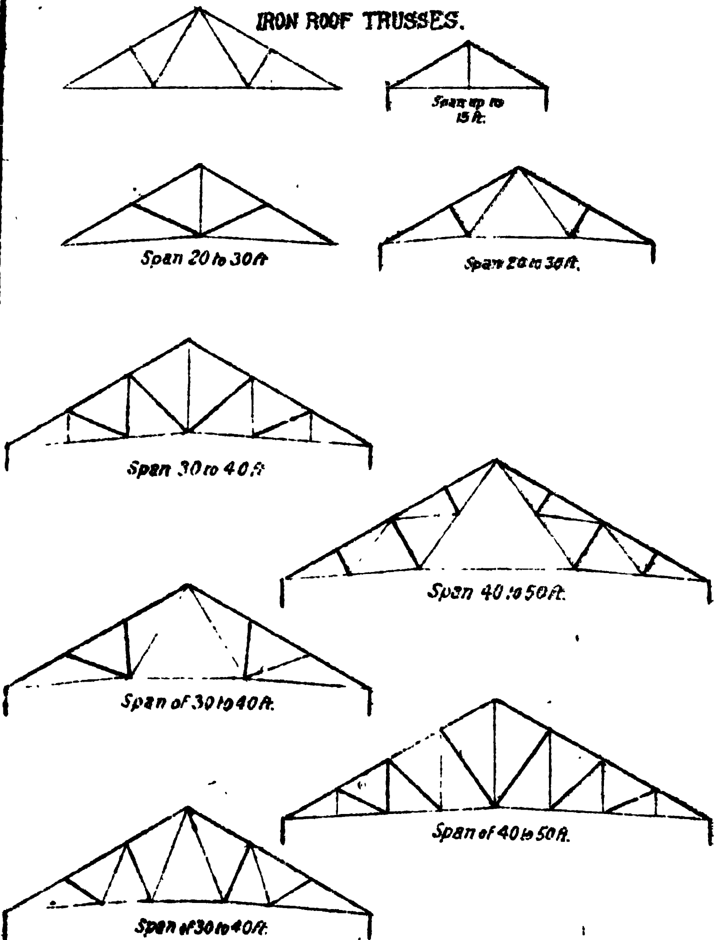


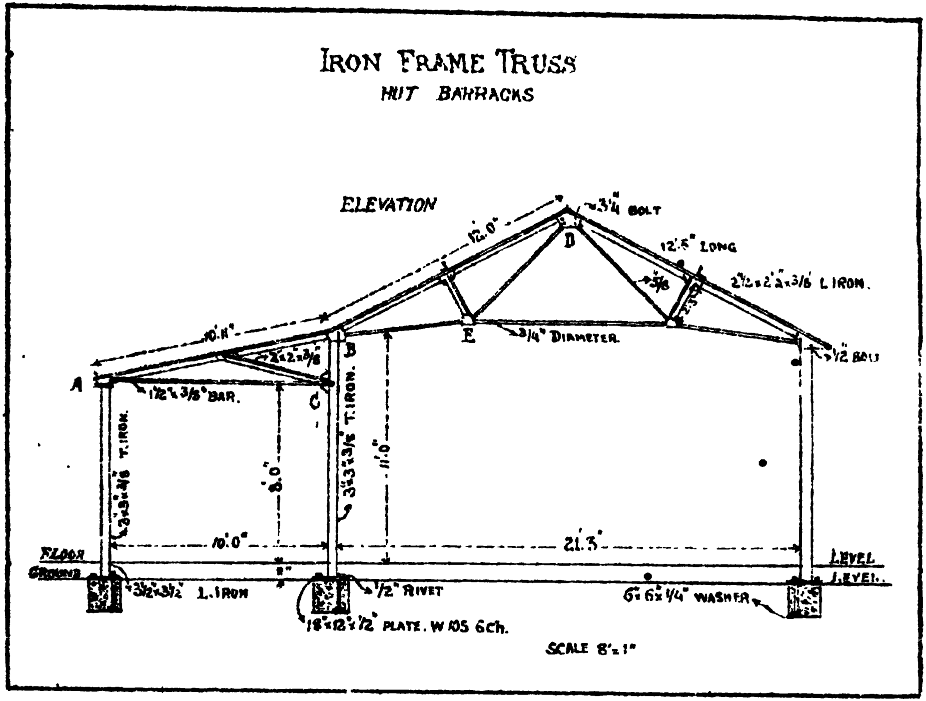
↔ DENOTES COMPRESSION

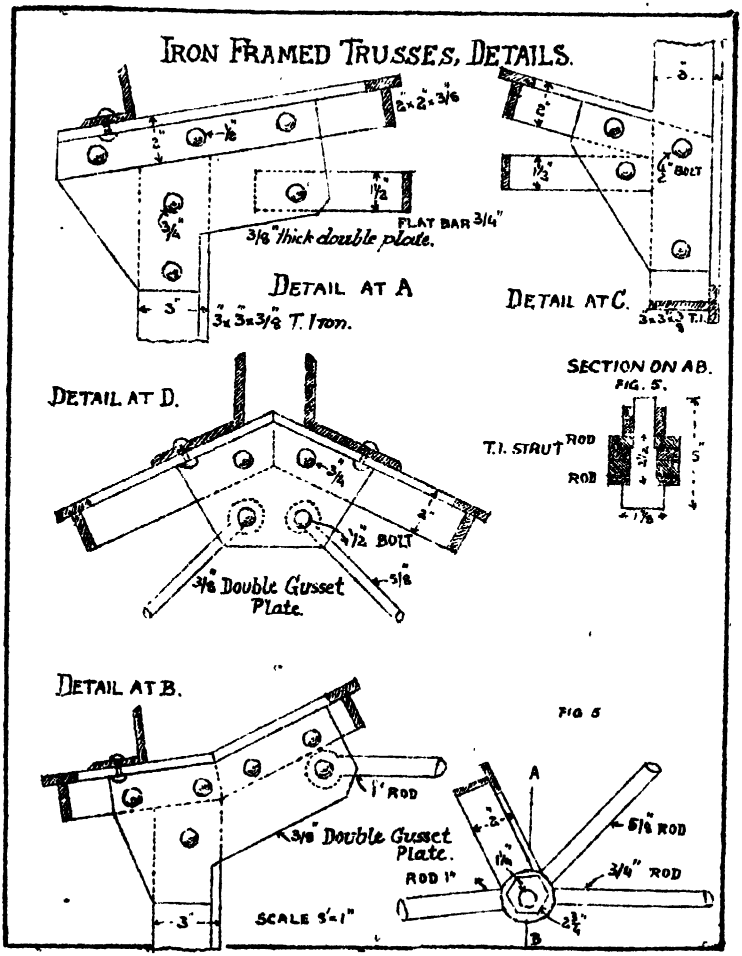
↔ DENOTES TENSION

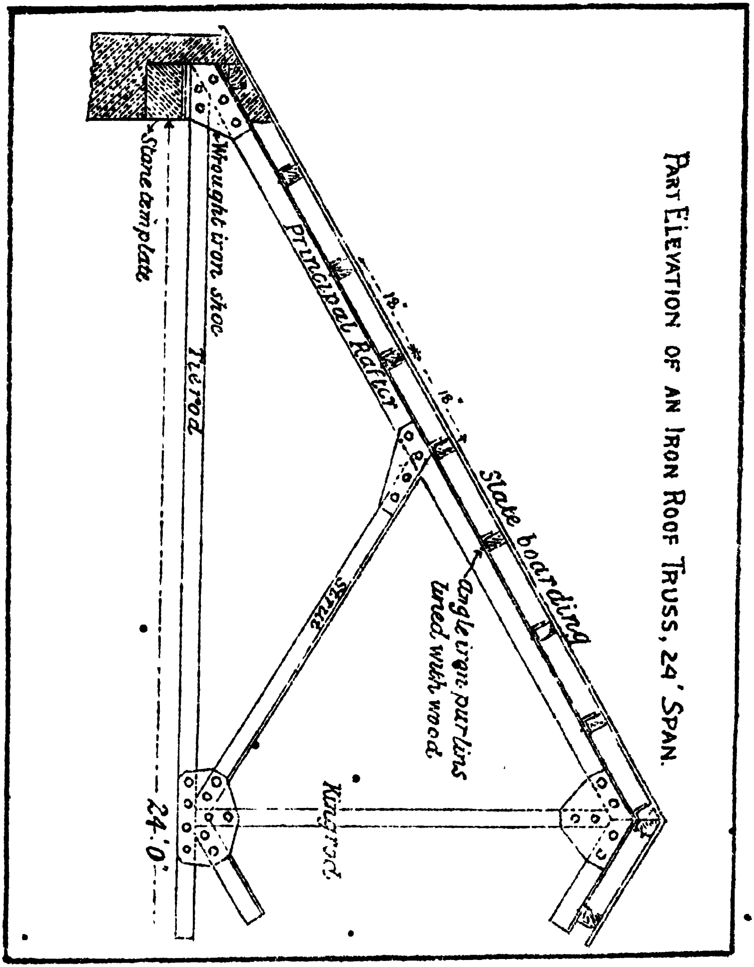


IRON ROOF TRUSSES.

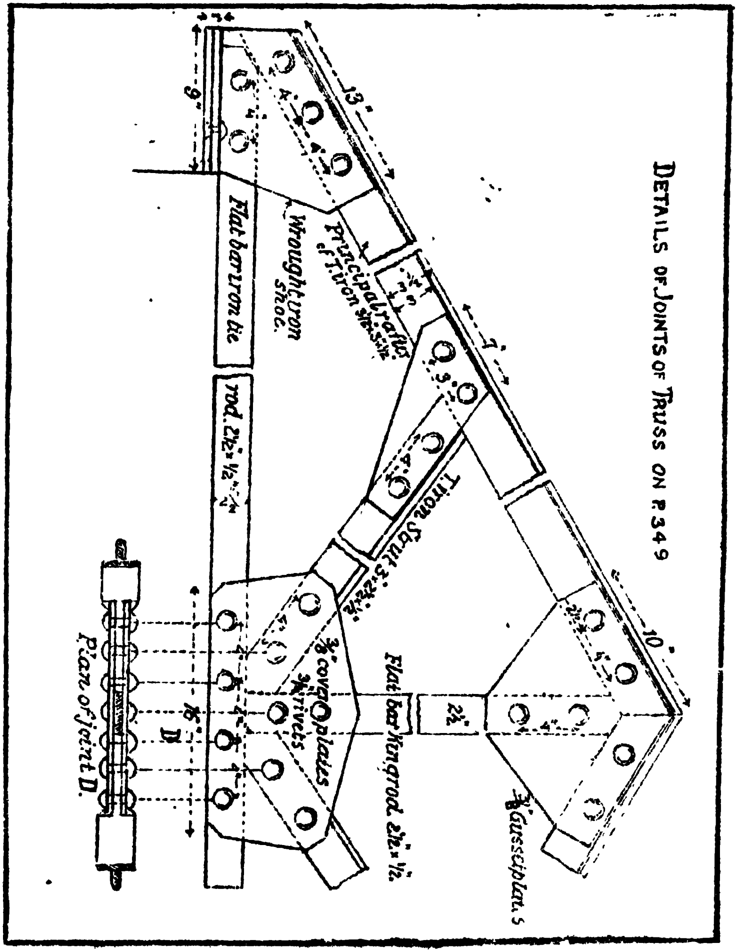


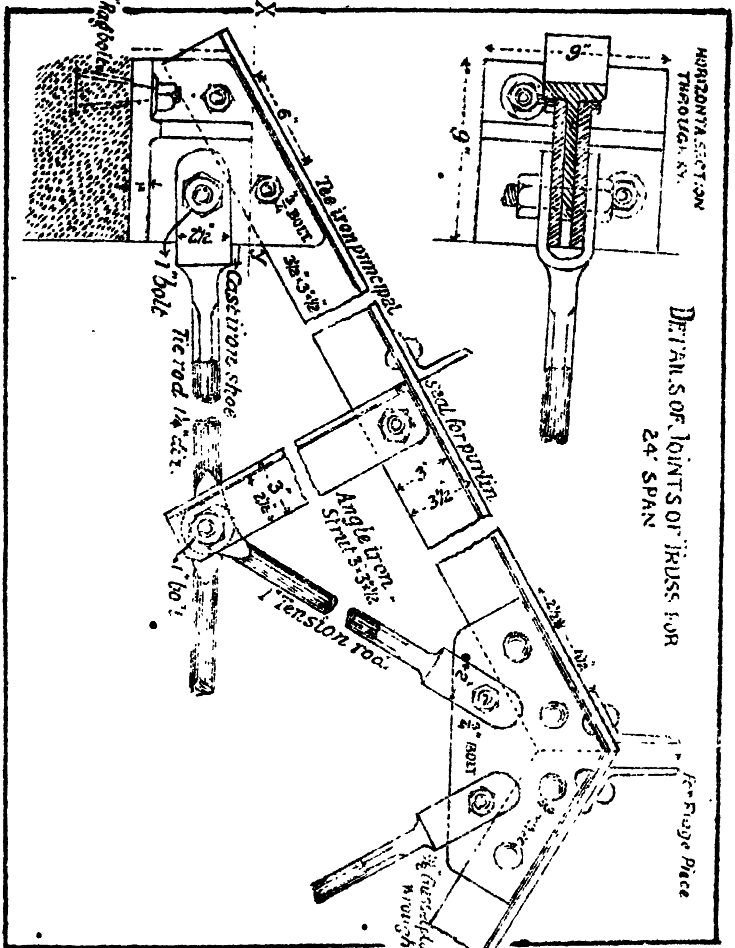

IRON FRAME TRUSS
HUT BARRACKS
ELEVATION
A
B
C
D
E
10'.11"
12'.0"
3/4" BOLT
12'.5" LONG
2½×2½×3/8 L IRON.
2×2×3/8
3/4" DIAMETER.
1/2" BOLT
1½×3/8" BAR.
3½×3½×3/8 T. IRON.
3½×3½×3/8 T. IRON.
8'.0"
11'.0"
10'.0"
21'.3"
FLOOR
GROUND
LEVEL
LEVEL.
3½×3½ L. IRON
1/2" RIVET
6×6×1/4" WASHER
18"×12"×1/2" PLATE. W IOS 6Ch.
SCALE 8'=1"

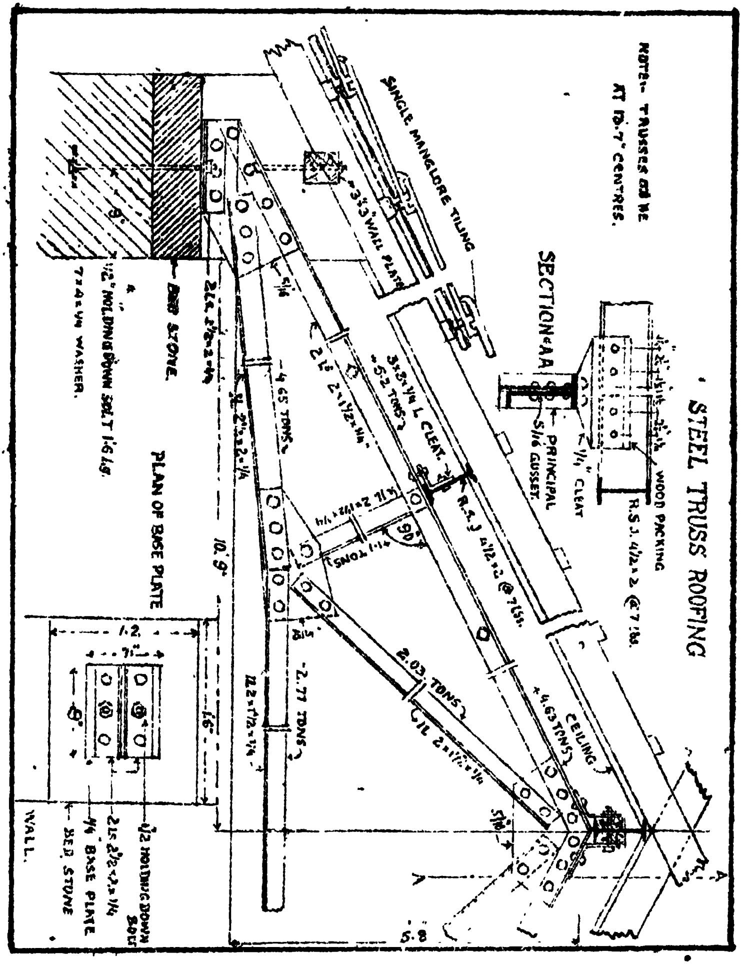

IRON FRAMED TRUSSES, DETAILS.
2"×2"×3/16
3/4"
1/2
FLAT BAR 3/4"
3/8" thick double plate.
DETAIL AT A
3"
3"×3"×3/8" T. Iron.
DETAIL AT C.
2" BOLT
3"×3"×3/8" T.I.
DETAIL AT D.
3/4
2"
1/2" BOLT
3/8" Double Gusset Plate.
5/8
SECTION ON AB.
FIG. 5.
T.I. STRUT
ROD
5"
1 7/8
DETAIL AT B.
1" ROD
3/8" Double Gusset Plate.
3"
SCALE 3'=1"
FIG 6
A
B
5/8" ROD
3/4" ROD
ROD 1"
2 3/4"

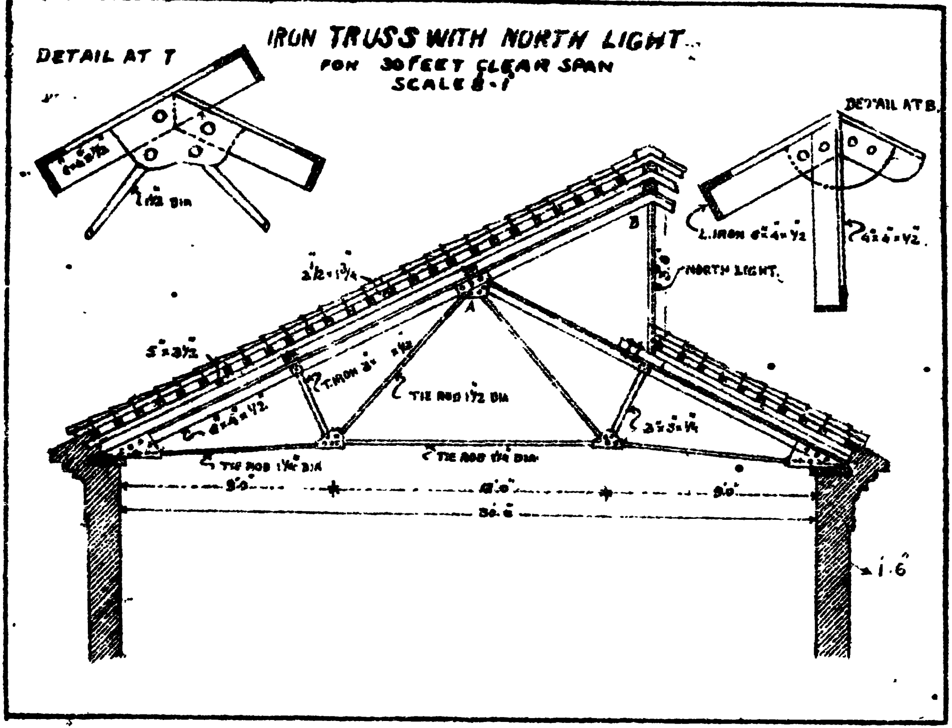


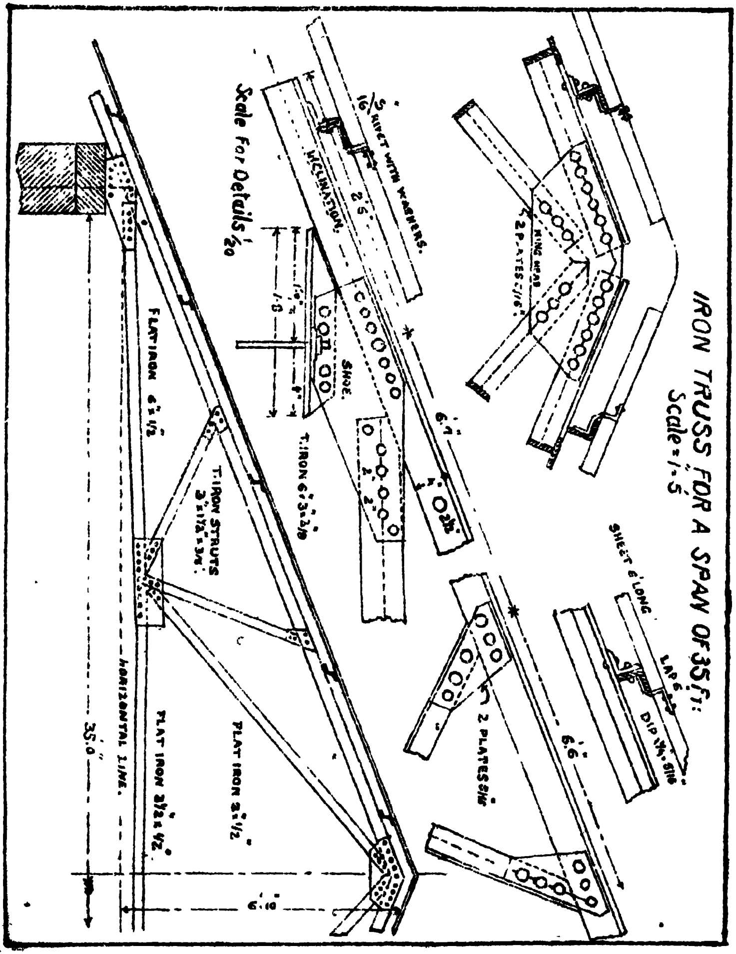
PART ELEVATION OF AN IRON ROOF TRUSS, 24' SPAN.

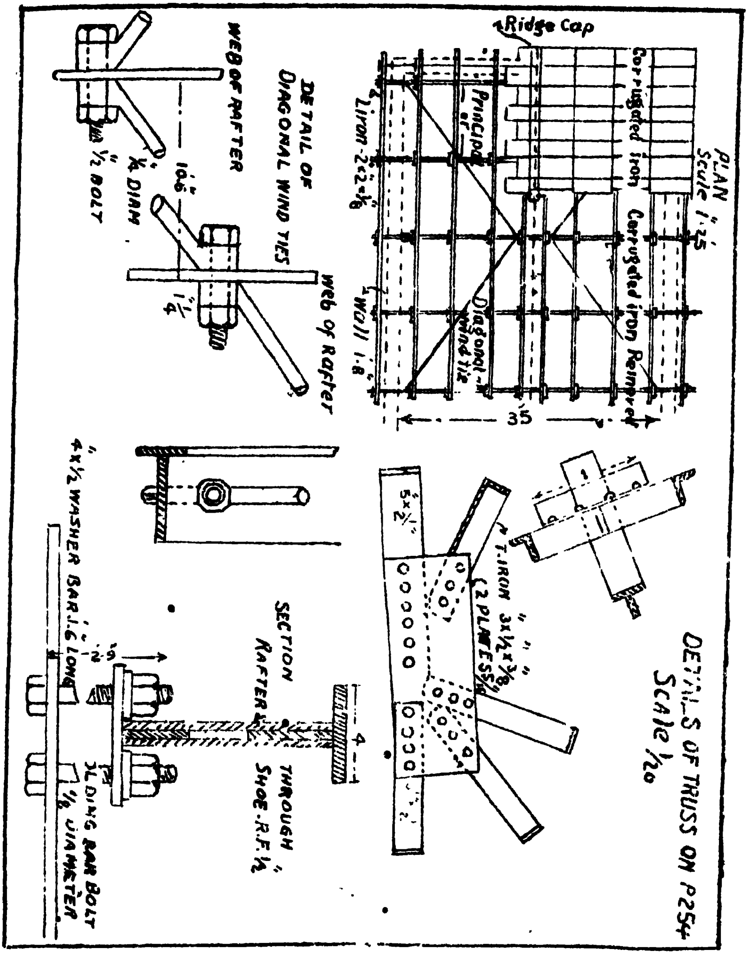

DETAILS OF JOINTS OF TRUSS ON P. 349
Flat bar iron tie rod
Wrought iron shoe
Principal rafter of T iron
T iron strut
⅜ cover plates
¾ rivets
Flat bar king rod 2½"×½"
⅜ Gusset plates
D
Plan of joint D.

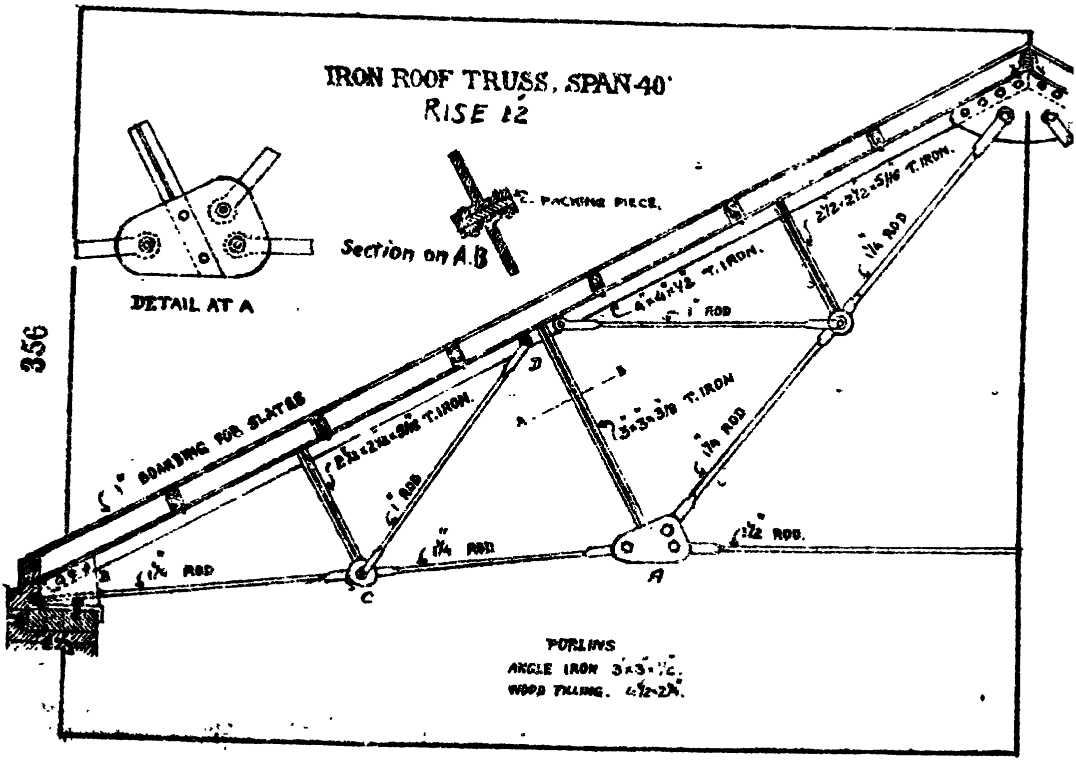

DETAILS OF JOINTS OF TRUSS FOR 24' SPAN
HORIZONTAL SECTION THROUGH XY
9"
9"
¾" Ragbolts
Tee iron principal
6"
¾" bolt
2½"
3½"×3½"
1" bolt
Cast iron shoe
Tie rod 1¼" dia.
Seat for purlin
3"
3½"
3"
2½"
Angle iron Strut 3×3½
1" bolt
1" tension rod
2½"
2"
¾" bolt
for Ridge Piece


STEEL TRUSS ROOFING
SECTION AA
SINGLE MANGLORE TILING
WOOD PACKING
PRINCIPAL
5/16 GUSSET
CEILING
PLAN OF BASE PLATE
BED STONE
WALL

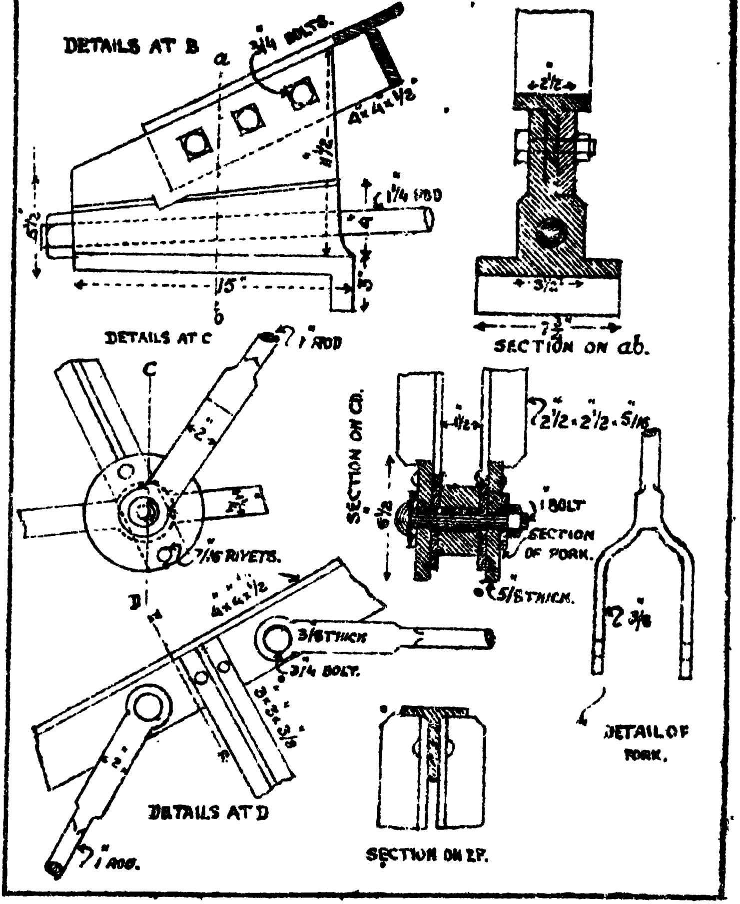

IRON TRUSS WITH NORTH LIGHT
FOR 30 FEET CLEAR SPAN
SCALE 8-1
DETAIL AT T
DETAIL AT B.
NORTH LIGHT
L. IRON 6" 4" ½
TIE ROD 1½ DIA
A
B
1.6"

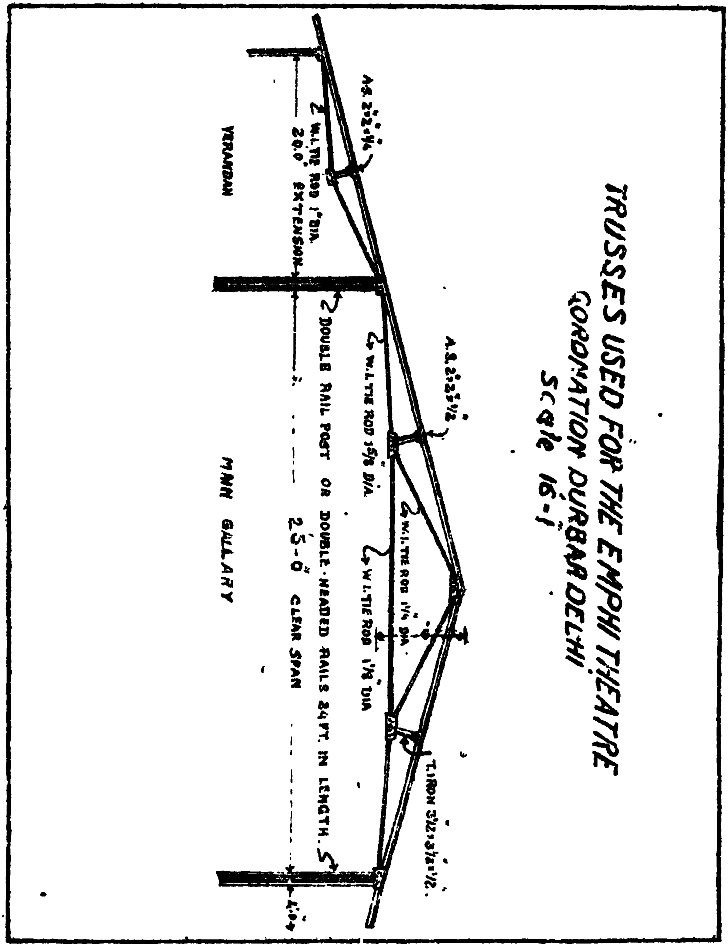

IRON TRUSS FOR A SPAN OF 35 FT.
Scale for Details 1/20
5/16" RIVET WITH WASHERS.
INCLINATION.
SHOE.
T IRON STRUTS
FLAT IRON 6"x1/2"
FLAT IRON
HORIZONTAL LINE.
35'0"
6'10"
6'7"
6'6"
2 PLATES 5/16"
SHEET 6' LONG
LAP 6"


DETAILS OF TRUSS ON P254
Scale 1/20
PLAN
Scale 1:25
Ridge Cap
Corrugated iron
Corrugated iron Removed
Principal
Diagonal wind tie
Wall
35
DETAIL OF DIAGONAL WIND TIES
WEB OF RAFTER
Web of Rafter
DIAM
BOLT
SECTION
RAFTERS
THROUGH
SHOE. R.F.
T. IRON
(2 PLATES
WASHER BAR
BOLT
DIAMETER

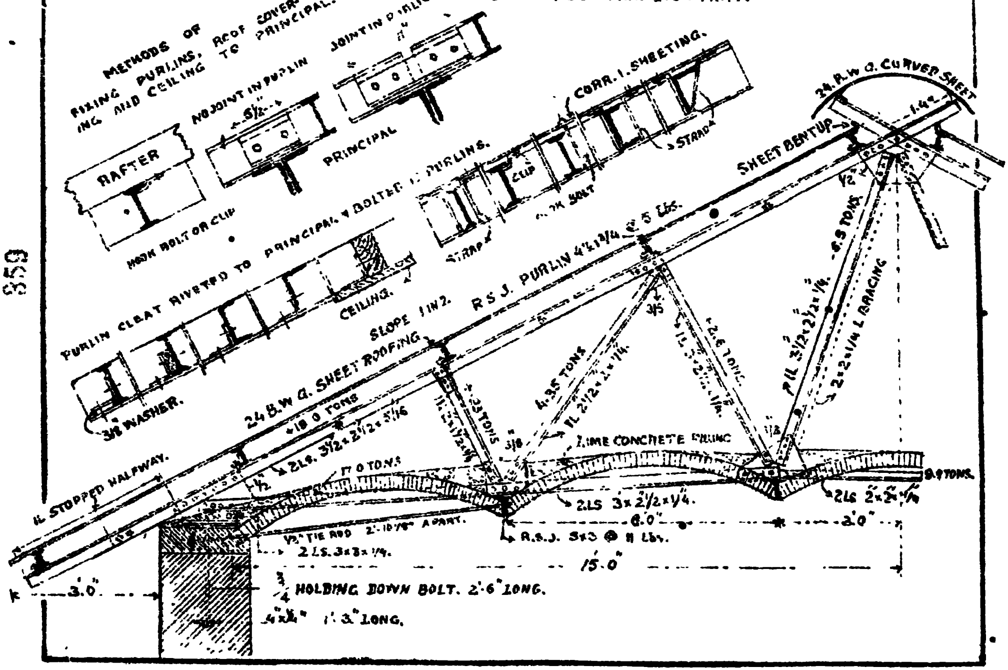

IRON ROOF TRUSS, SPAN 40'
RISE 12'
DETAIL AT A
Section on A.B
PACKING PIECE.
1" BOARDING FOR SLATES
T. IRON.
T. IRON
1" ROD
1¼ ROD
1½ ROD
A
B
C
D
PURLINS
ANGLE IRON
WOOD FILLING.

DETAILS OF IRON TRUSS ON P.256.

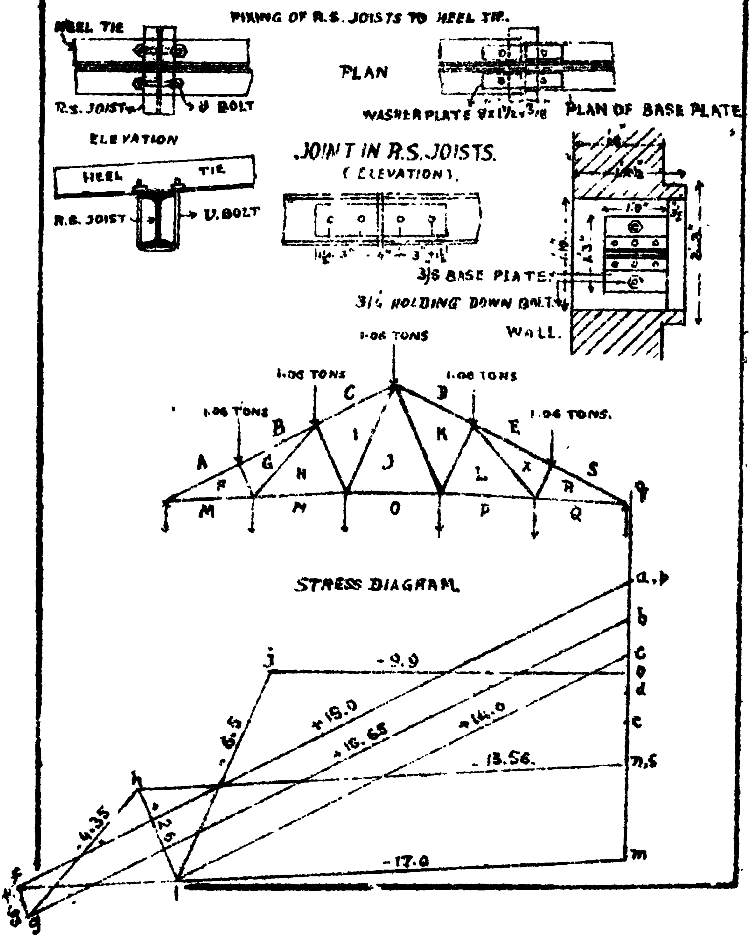


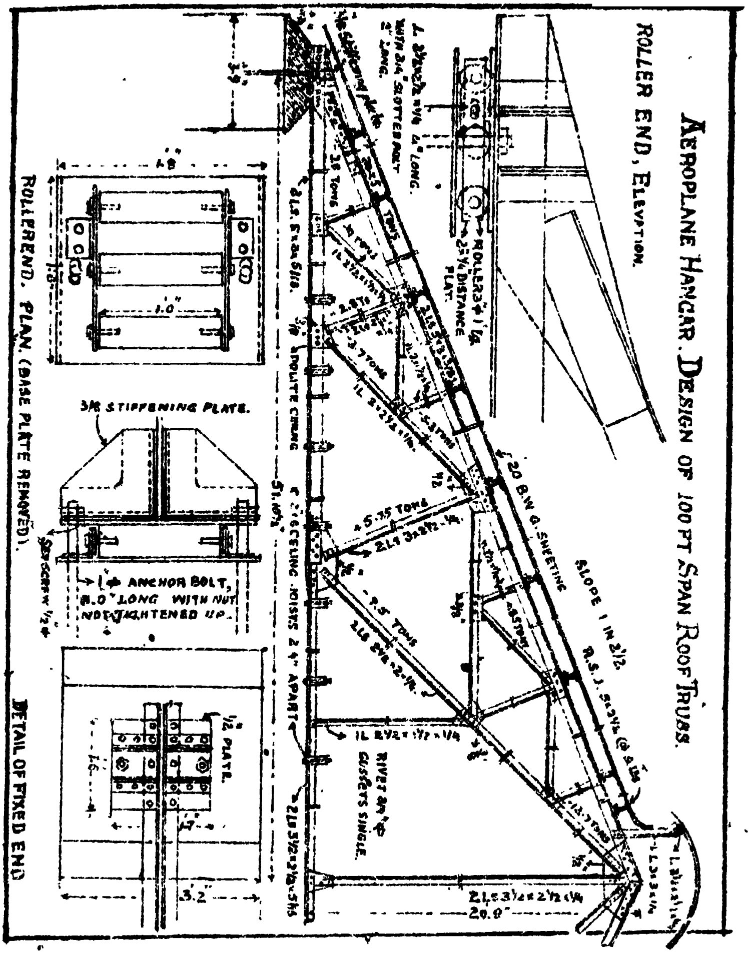

TRUSSES USED FOR THE EMPHI THEATRE
CORONATION DURBAR DELHI
Scale 16-1"
A.S. 2½x2½x½
2 W.I. TIE ROD 1" DIA.
20'-0" EXTENSION
VERANDAH
A.S. 2½x2½x½
2 DOUBLE RAIL POST OR DOUBLE-HEADED RAILS 24FT. IN LENGTH.
W.I. TIE ROD 1⅝ DIA.
W.I. TIE ROD 1¼ DIA.
W.I. TIE ROD 1⅛ DIA.
T. IRON 3½x3½x½.
25'-0" CLEAR SPAN
MAIN GALLARY
4'-0"

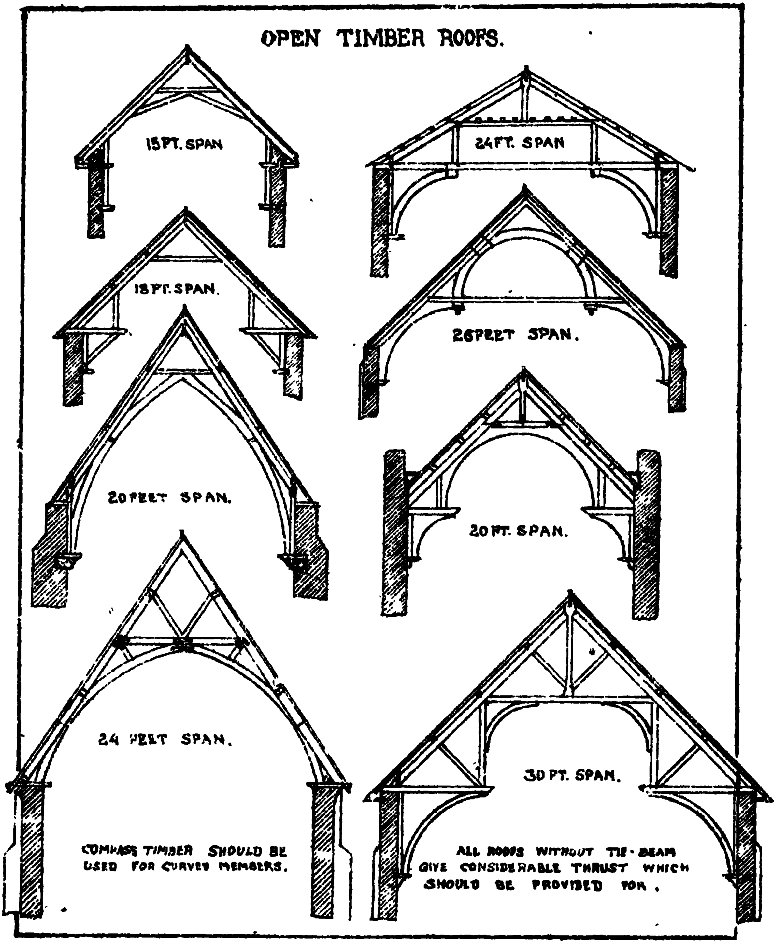
STEEL TRUSS WITH JACK ARCH CEILING, 30' SPAN. 12' 6" APART.

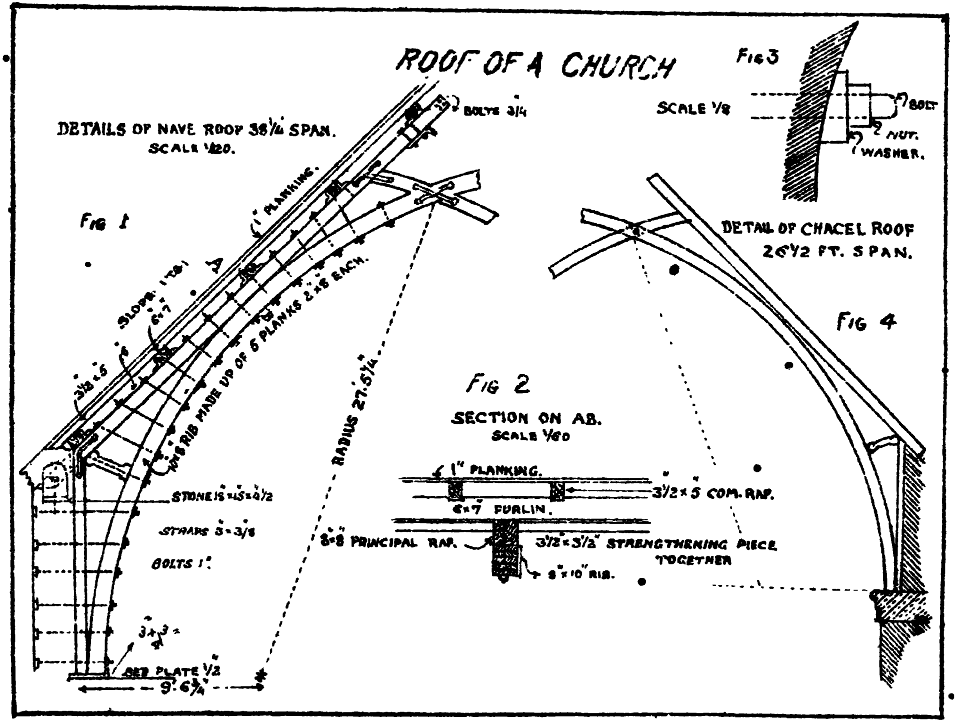


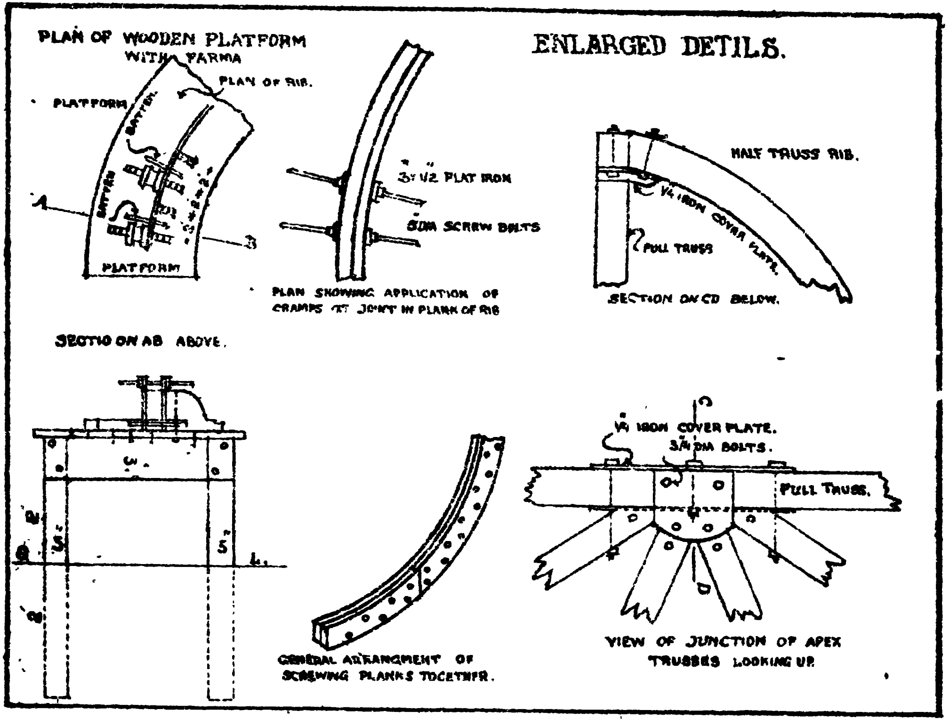
DETAILS OF TRUSS ON P.359



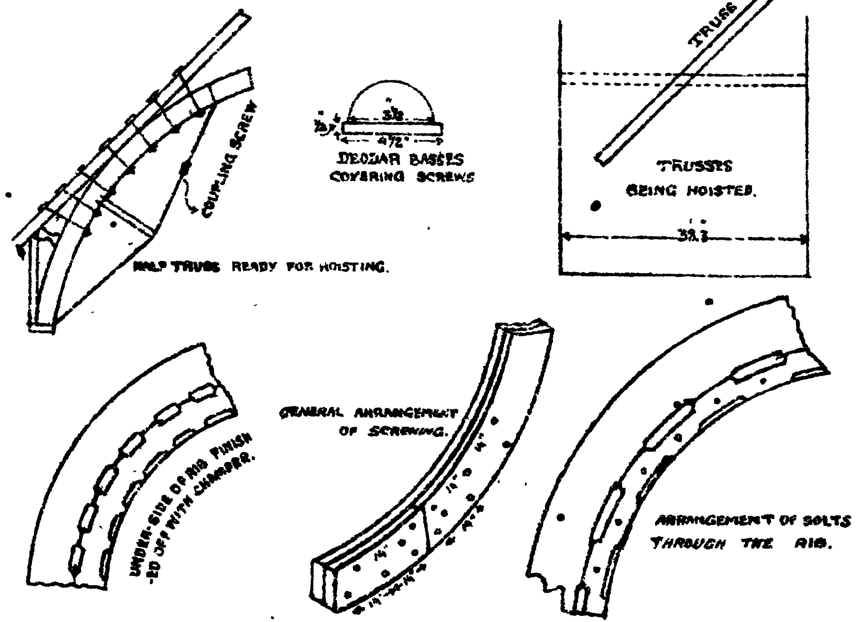

AEROPLANE HANGAR. DESIGN OF 100 FT SPAN ROOF TRUSS.
ROLLER END, ELEVATION.
SLOPE 1 IN 2½.
20 B.W.G. SHEETING
2' × 2' CEILING JOISTS 2' 4" APART
RIVET ¾" ⌀ GUSSETS SINGLE.
⅜ STIFFENING PLATE.
ANCHOR BOLT, 5.0" LONG WITH NUT NOT TIGHTENED UP.
½ PLATE.
ROLLER END. PLAN. (BASE PLATE REMOVED).
DETAIL OF FIXED END
51.10½"
20.0"


OPEN TIMBER ROOFS.
15 FT. SPAN
24 FT. SPAN
18 FT. SPAN.
26 FEET SPAN.
20 FEET SPAN.
20 FT. SPAN.
24 FEET SPAN.
30 FT. SPAN.
COMPASS TIMBER SHOULD BE USED FOR CURVED MEMBERS.
ALL ROOFS WITHOUT TIE-BEAM GIVE CONSIDERABLE THRUST WHICH SHOULD BE PROVIDED FOR.

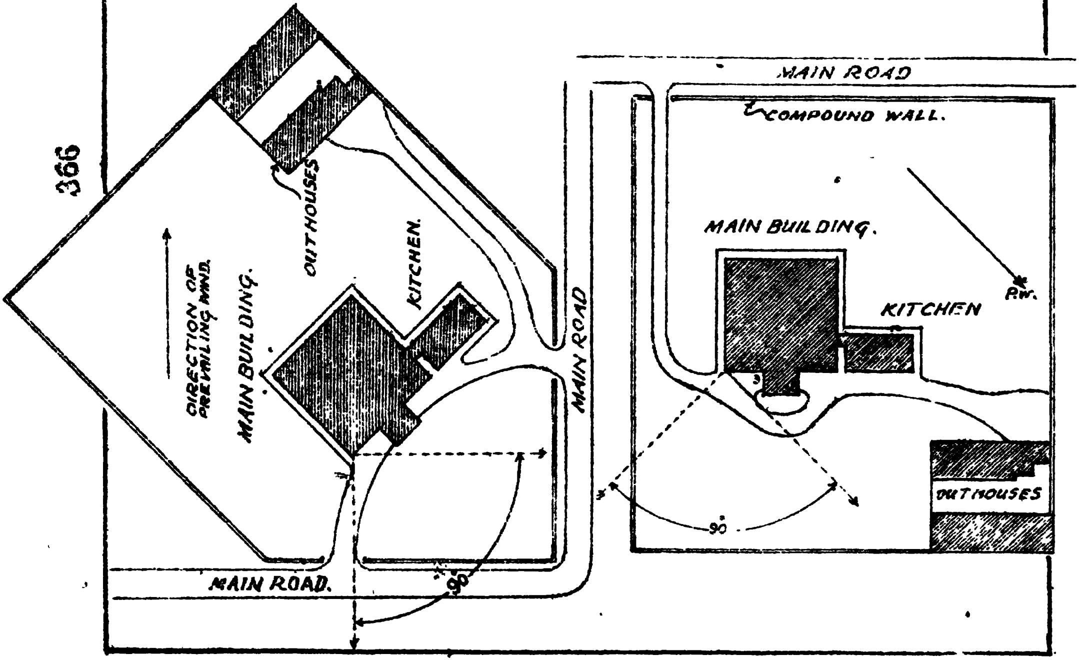

ROOF OF A CHURCH
DETAILS OF NAVE ROOF 38¼ SPAN.
SCALE 1/20.
Fig 1
BOLTS 3/4
1" PLANKING.
SLOPE 1 TO 1
A
6×7
3½×5
10×8 RIB MADE UP OF 5 PLANKS 2×8 EACH.
STONE 18×15×4½
STRAPS 3×3/8
BOLTS 1"
3×3×¼
BED PLATE ½"
9.6¾
RADIUS 27.5¼
Fig 2
SECTION ON AB.
SCALE 1/60
1" PLANKING.
3½×5 COM. RAF.
6×7 PURLIN.
8×8 PRINCIPAL RAF.
3½×3½ STRENGTHENING PIECE TOGETHER
8×10 RIB.
Fig 3
SCALE 1/8
BOLT
NUT.
WASHER.
DETAIL OF CHACEL ROOF
26½ FT. SPAN.
Fig 4

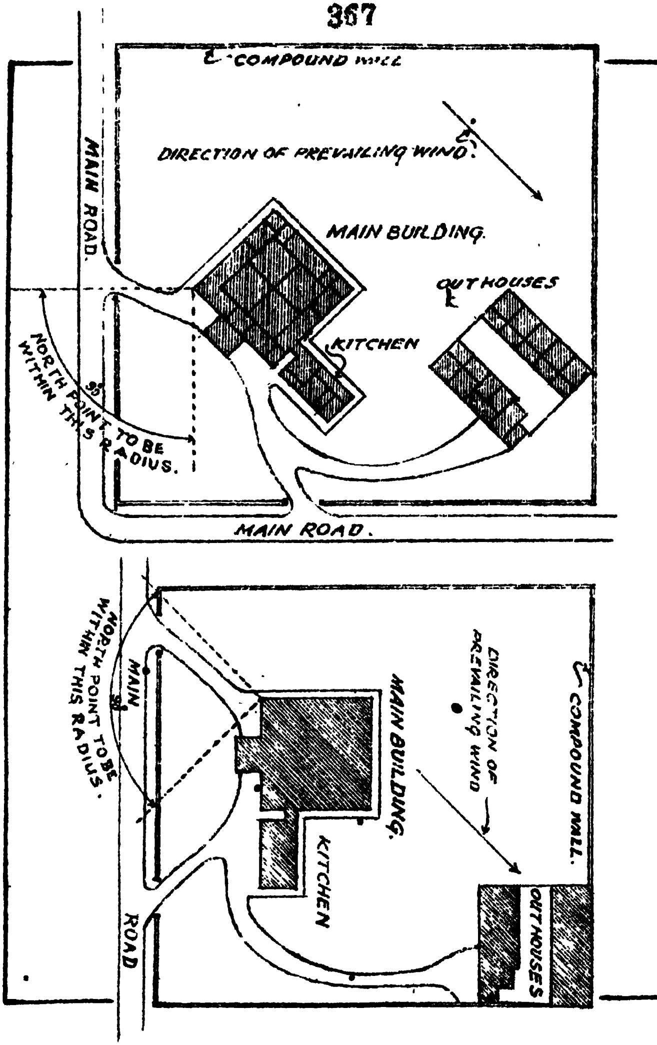

ENLARGED DETILS.
PLAN OF WOODEN PLATFORM
WITH FARMA
PLAN OF RIB.
PLATFORM
BATTEN
BATTEN
PLATFORM
A
B
3" 1/2 FLAT IRON
5DIA SCREW BOLTS
PLAN SHOWING APPLICATION OF
CRAMPS AT JOINT IN PLANK OF RIB
HALF TRUSS RIB.
1/4 IRON COVER PLATE
FULL TRUSS
SECTION ON CD BELOW.
SECTIO ON AB ABOVE.
GENERAL ARRANGMENT OF
SCREWING PLANKS TOGETHER.
1/4 IRON COVER PLATE.
3/4 DIA BOLTS.
FULL TRUSS.
VIEW OF JUNCTION OF APEX
TRUSSES LOOKING UP.

DETAILS CONTINUED.



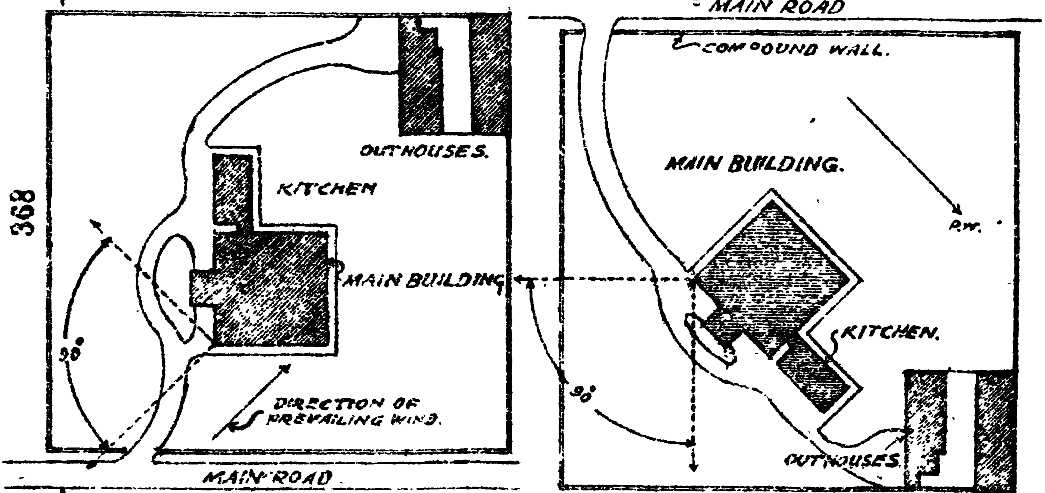
LAY-OUT PLANS.





LAY-OUT PLANS.

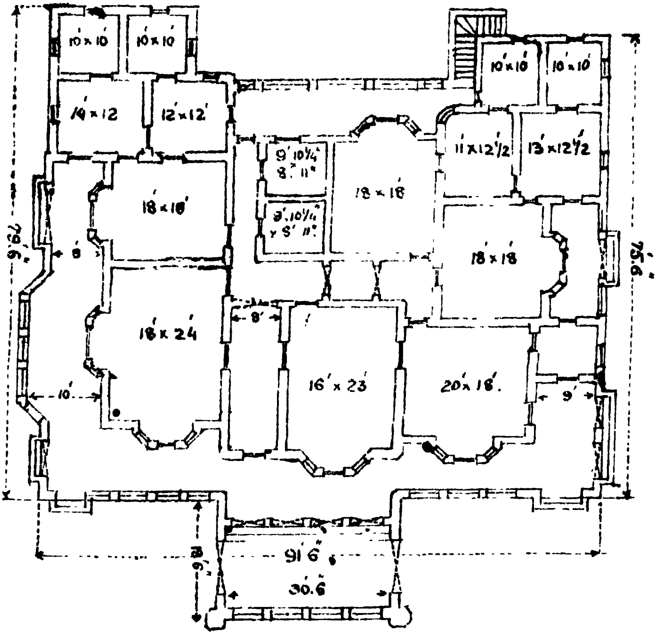
LAY-OUT PLANS.



HOUSES OF EUROPEAN FASHION

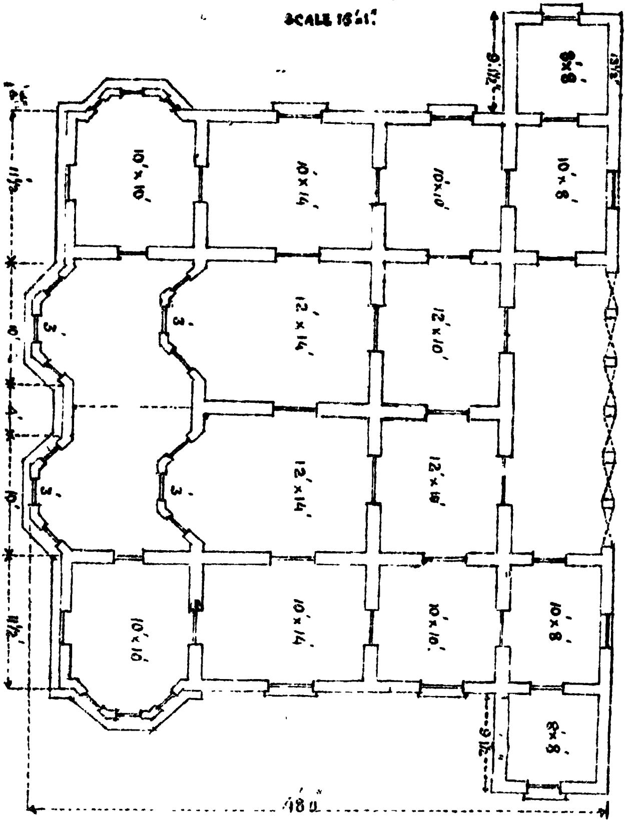
PLAN No. 1

SCALE, 30'=1"

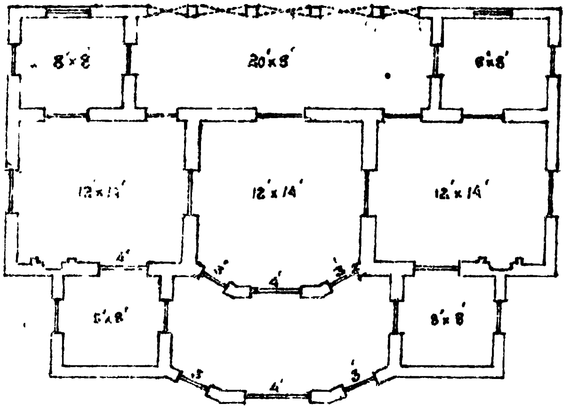


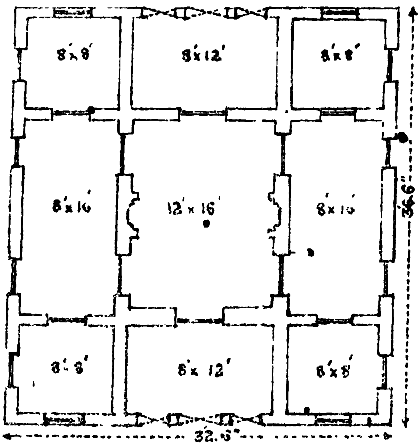
PLAN No. 2

SCALE 16' = 1"



PLAN No. 3

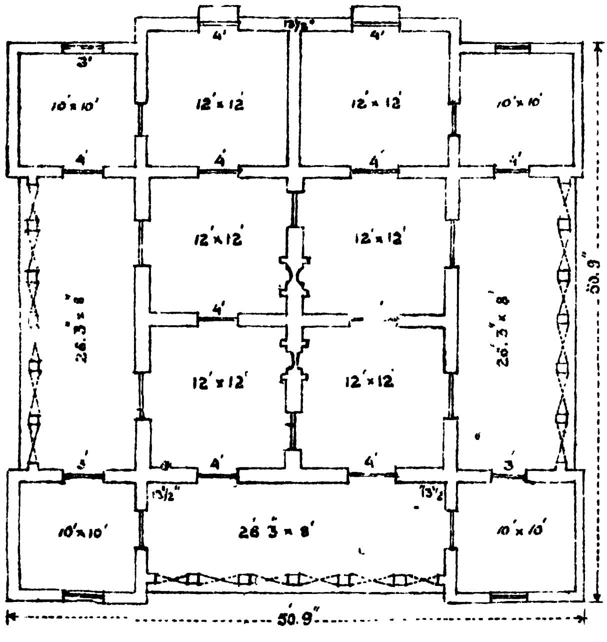




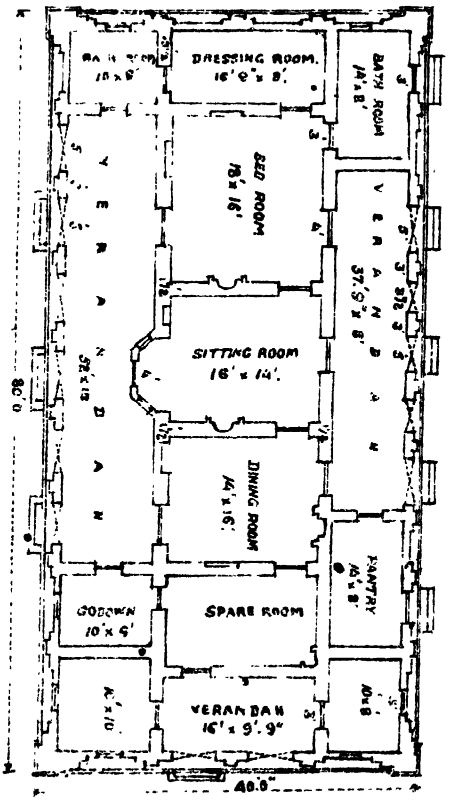
PLAN No. 4

SCALE, 16'=1"

PLAN No. 5



SCALE, 16'=1"

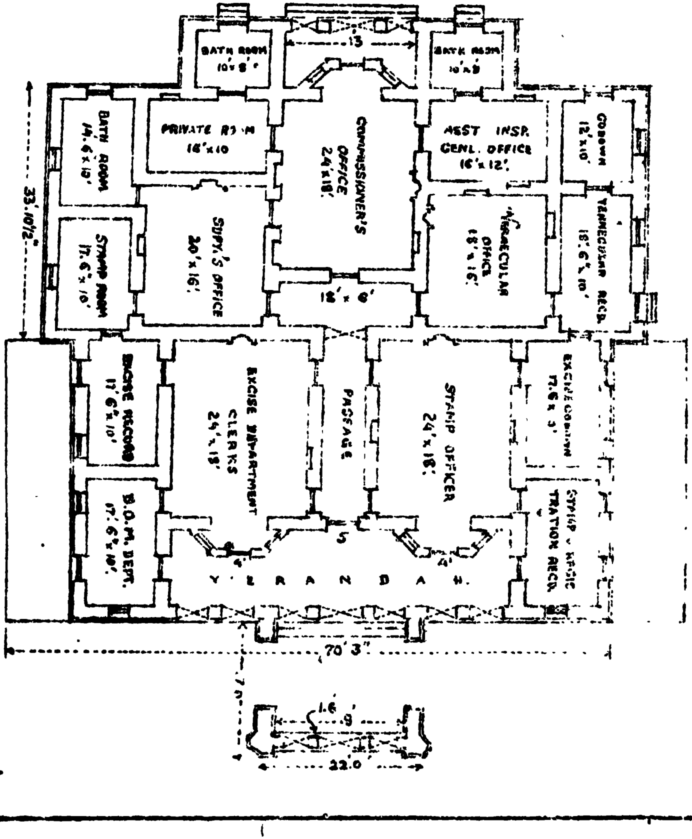


PLAN No. 6.

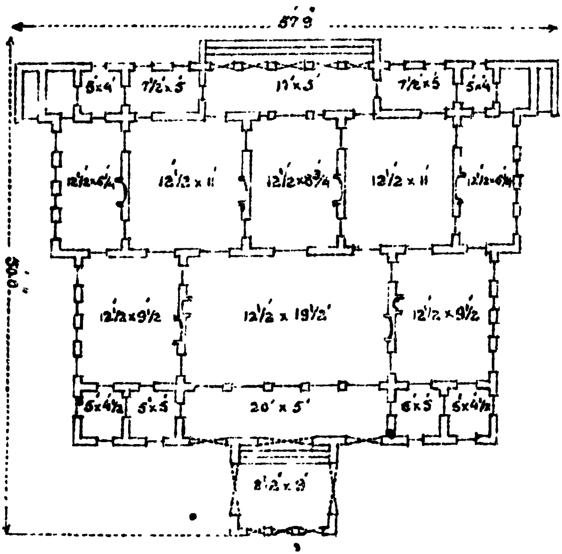
SCALE 24=1.

PLAN No. 7.

SCALE 25'=1".

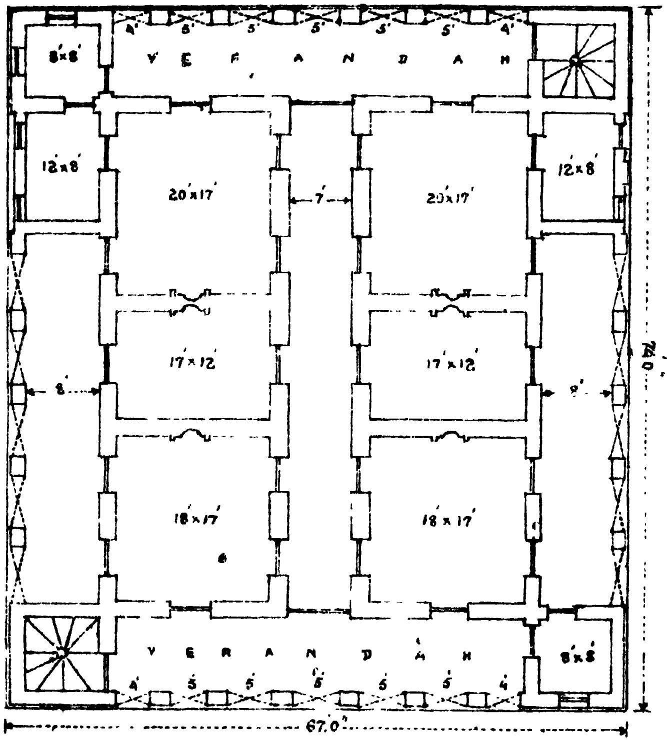


PLAN No. 8

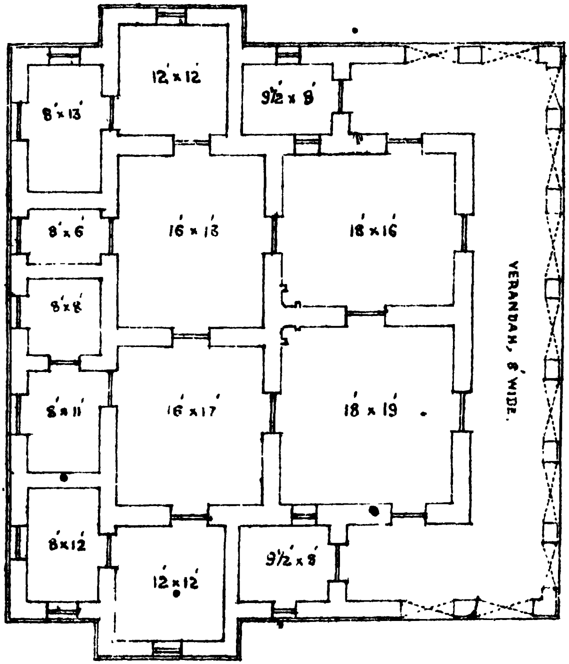


SCALE 16'=1"

PLAN No. 9

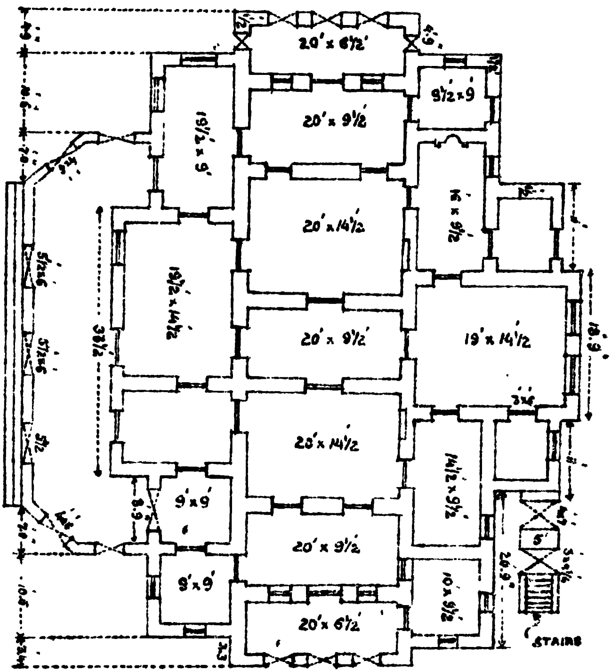

8'x8'
V E R A N D A H
12'x8'
20'x17'
7'
20'x17'
12'x8'
17'x12'
17'x12'
8'
8'
18'x17'
18'x17'
V E R A N D A H
8'x8'
67.0"
SCALE, 10 = 1'

PLAN No. 10.



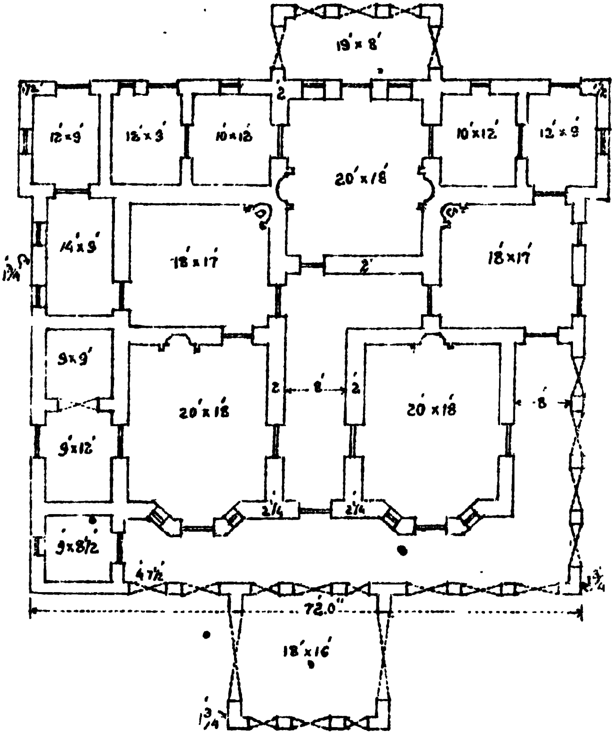
SCALE 20' = 1".

PLAN No. 11



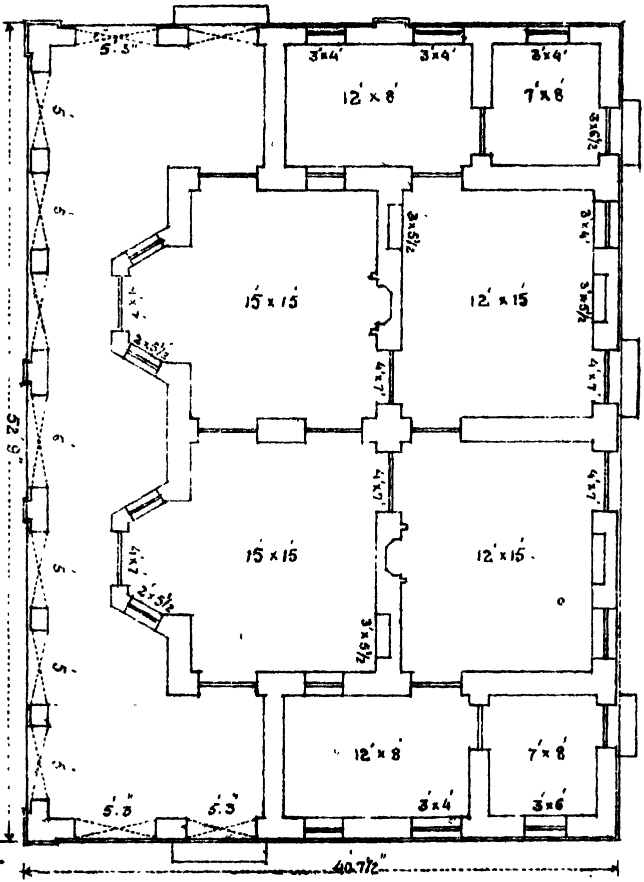
SCALE, 24' = 1"

PLAN No. 12

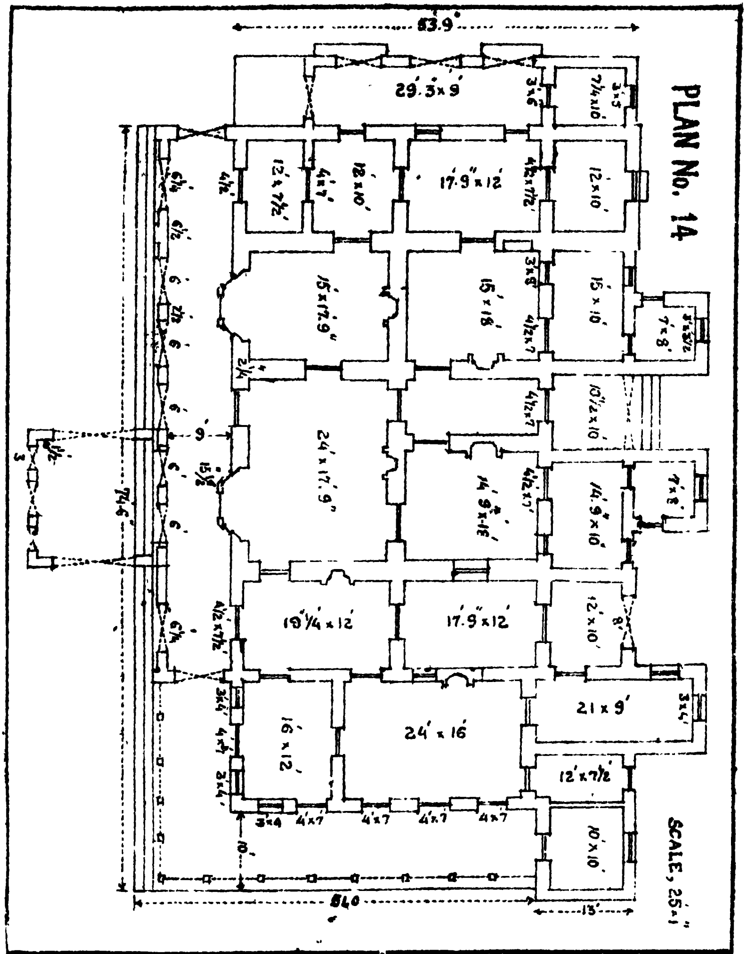


SCALE, 25' = 1"

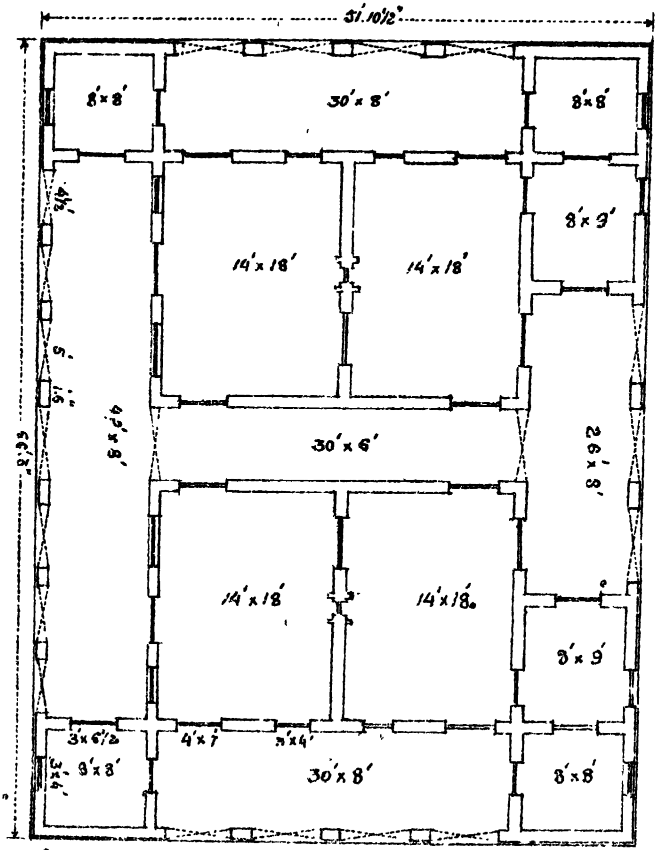
PLAN No. 13



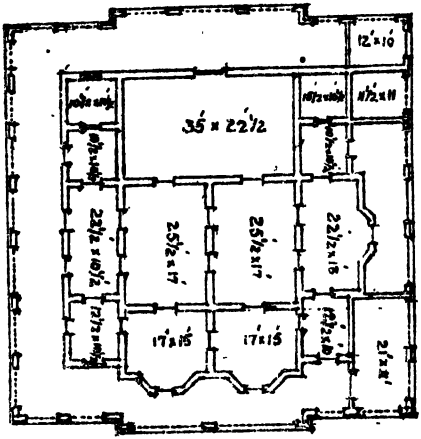
SCALE, 12' = 1".


PLAN No. 14
SCALE, 25'=1"

PLAN No. 15

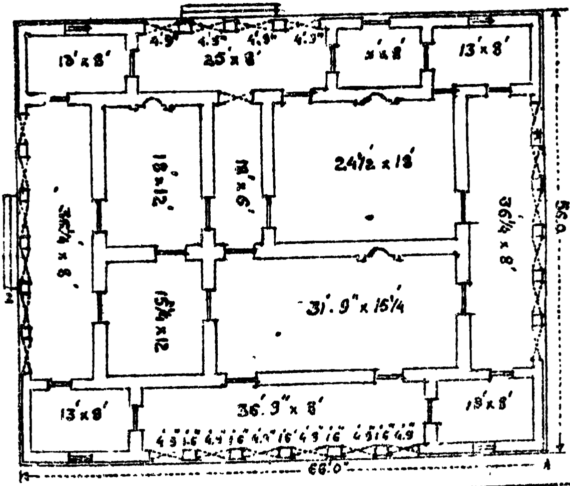


SCALE, 16' = 1"



PLAN No. 16

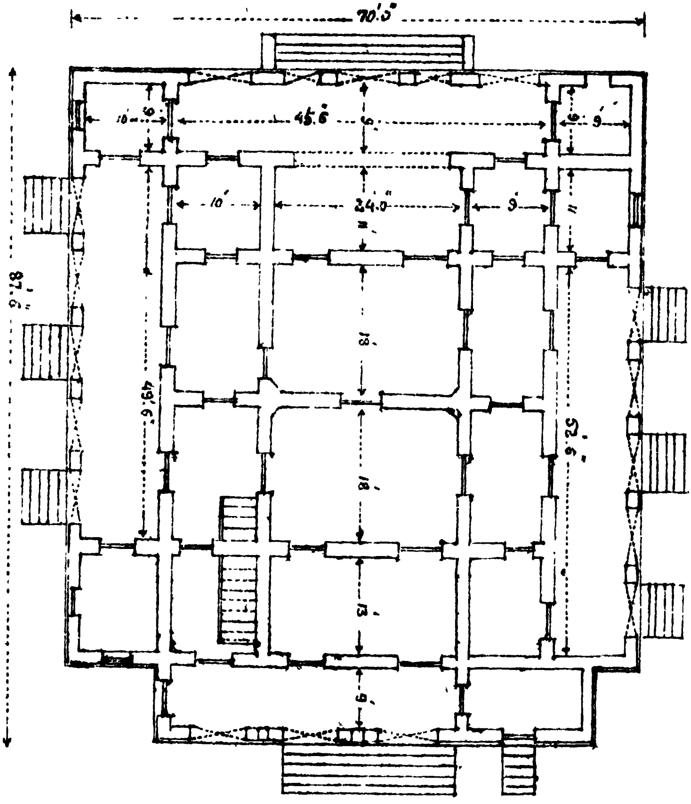
SCALE, 40'=1"



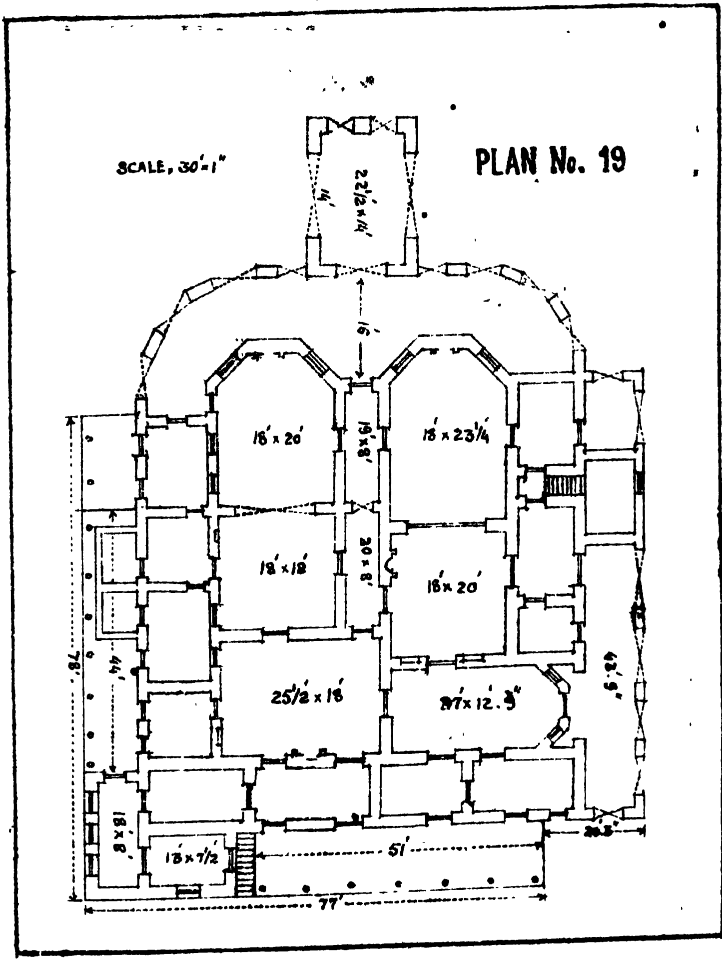
PLAN No. 17

SCALE, 24'=1"

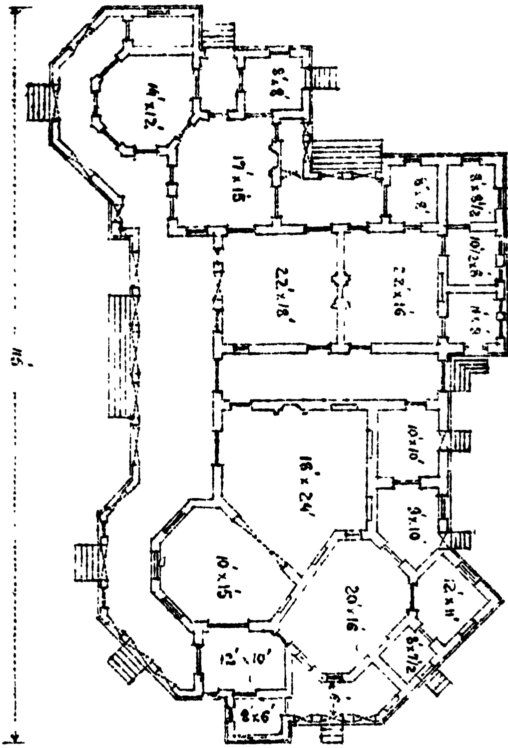
PLAN No. 18



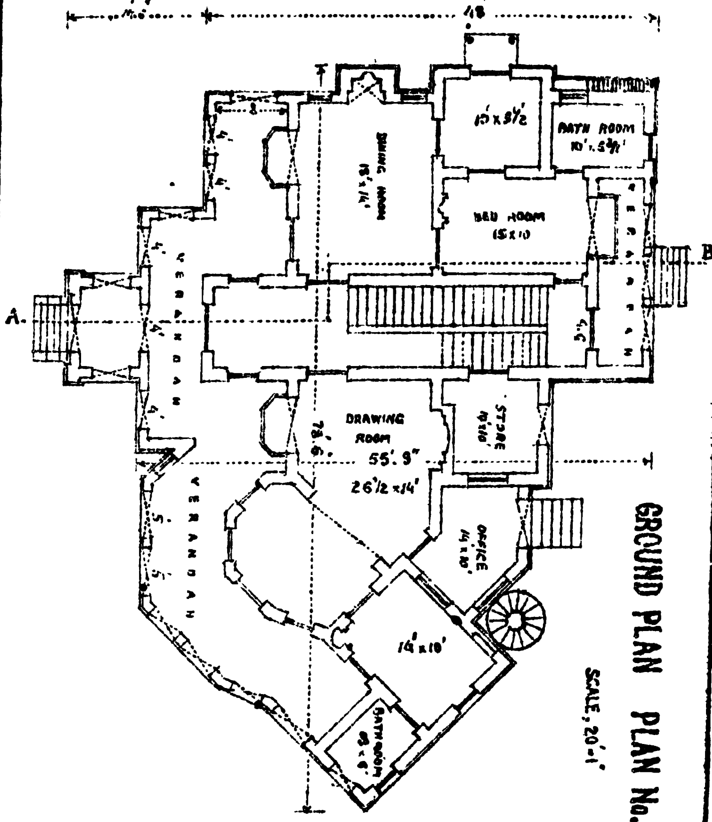
SCALE, 25' = 1 INCH


SCALE, 30'=1"
PLAN No. 19
22½' x 14'
14'
16'
18' x 20'
16' x 8'
18' x 23¼'
18' x 18'
20 x 8'
18' x 20'
25½' x 18'
17' x 12' 3"
43' 5"
78'
44'
18' x 8'
13' x 7½'
51'
77'
20.3"

PLAN No. 20

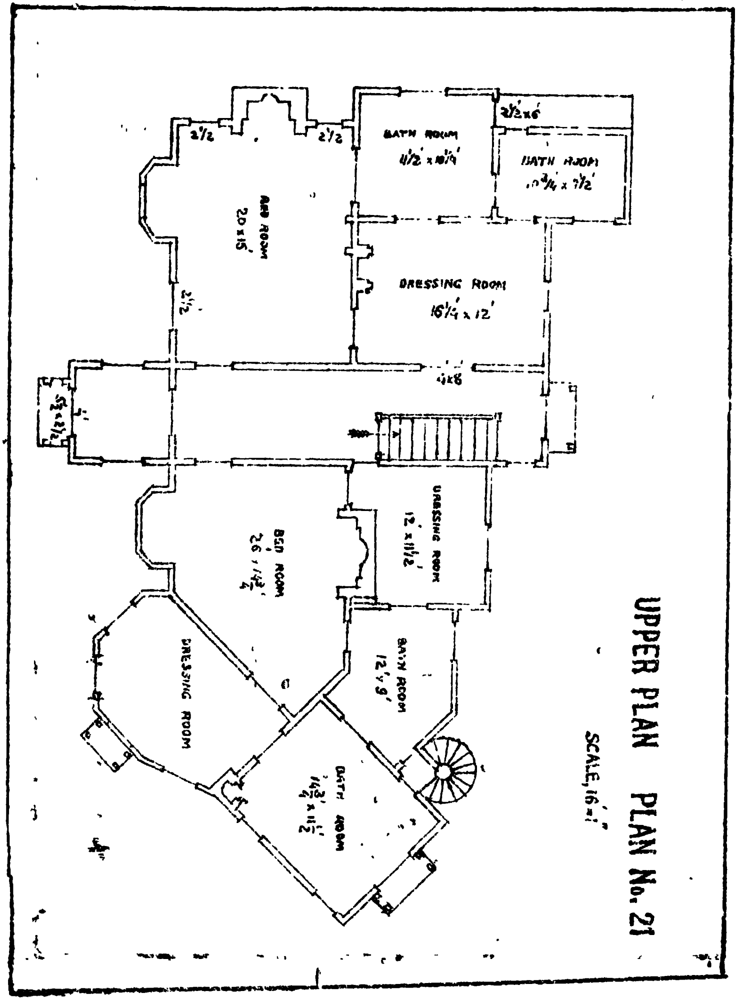


SCALE, 32' = 1".



GROUND PLAN No. 21.

SCALE, 20'-1"



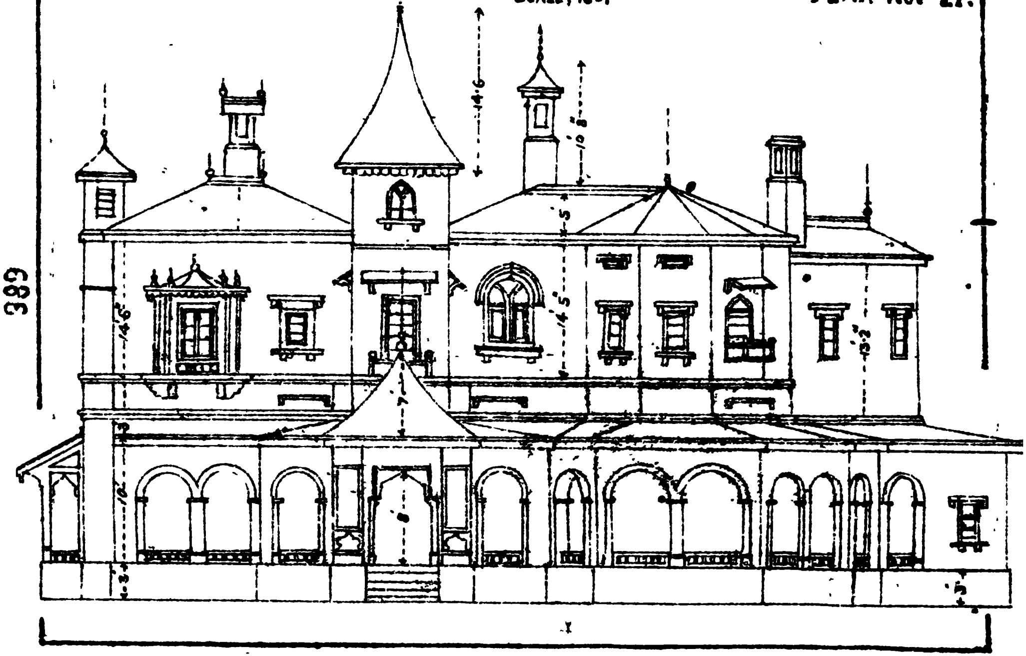
UPPER PLAN PLAN No. 21

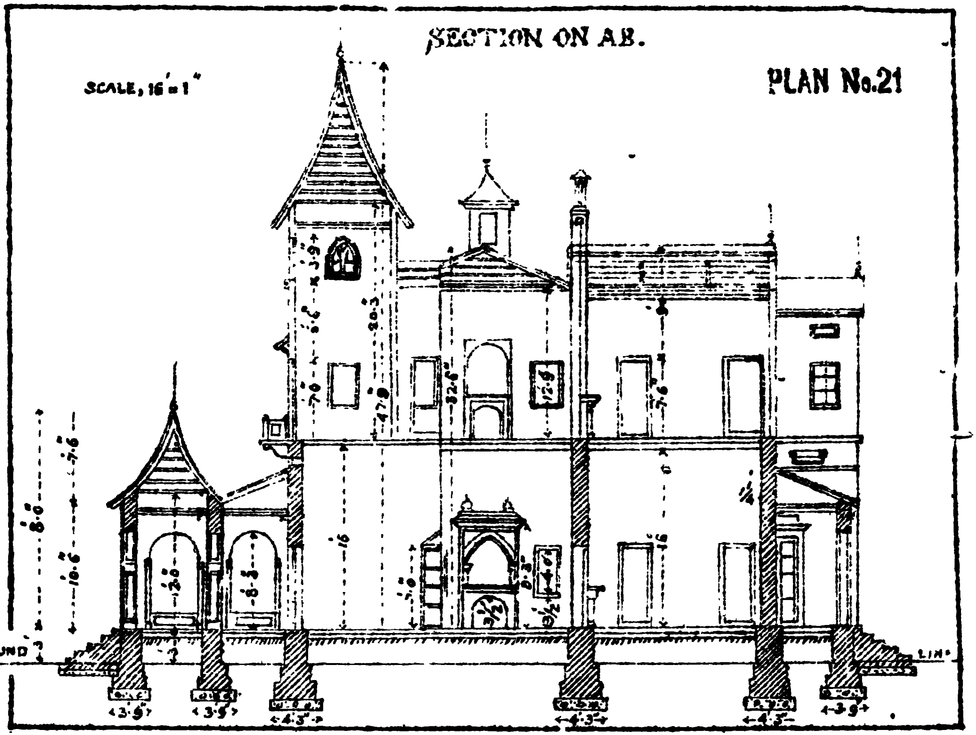
SCALE, 16' = 1"

FRONT ELEVATION

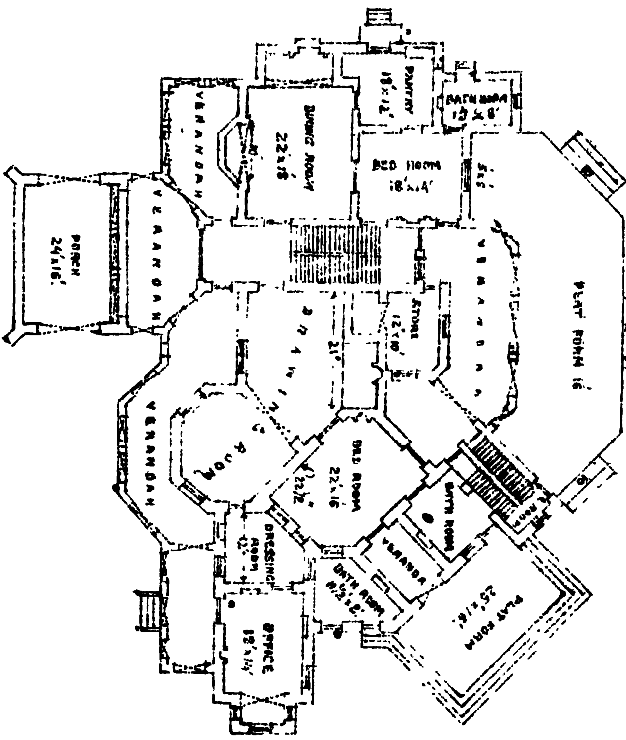
SCALE, 16'=1"

PLAN No. 21.




SECTION ON A.B.
SCALE, 16' = 1"
PLAN No.21

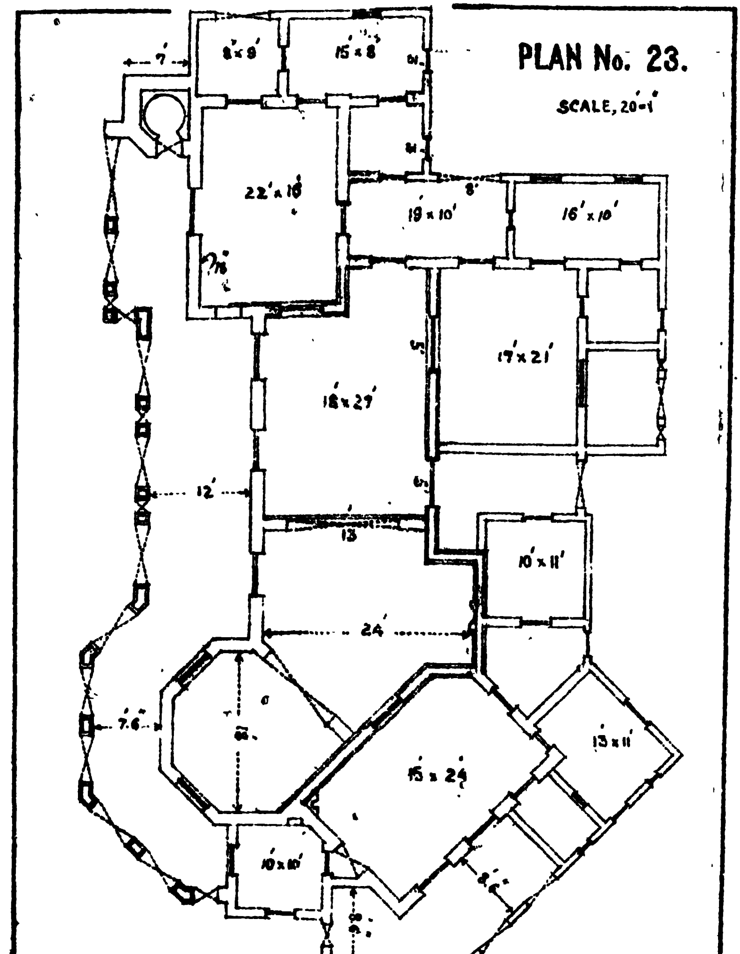
PLAN No. 22.



SCALE, 32'=1."

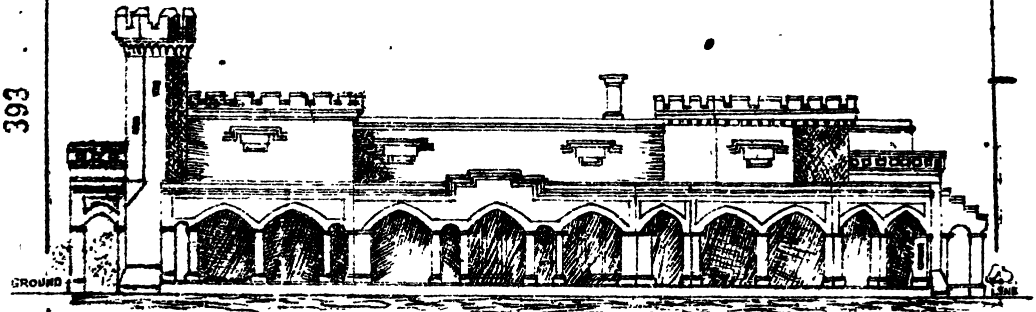
PLAN No. 23.

SCALE, 20'=1"



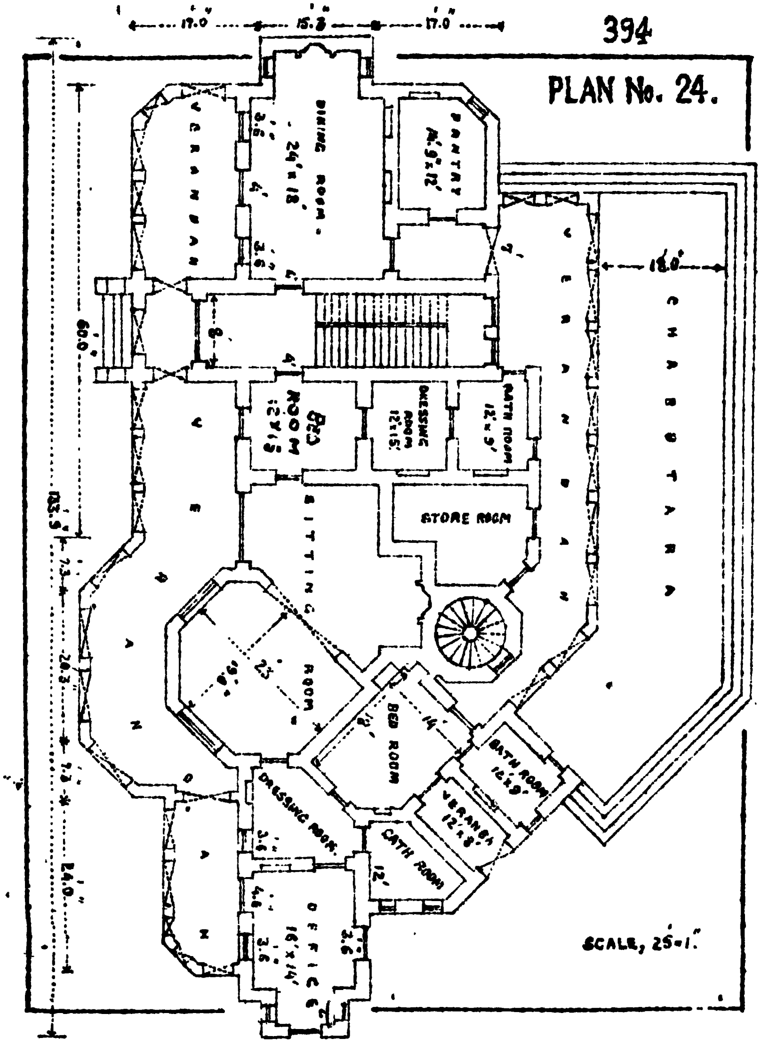
PLAN No. 23.

FRONT ELEVATION.



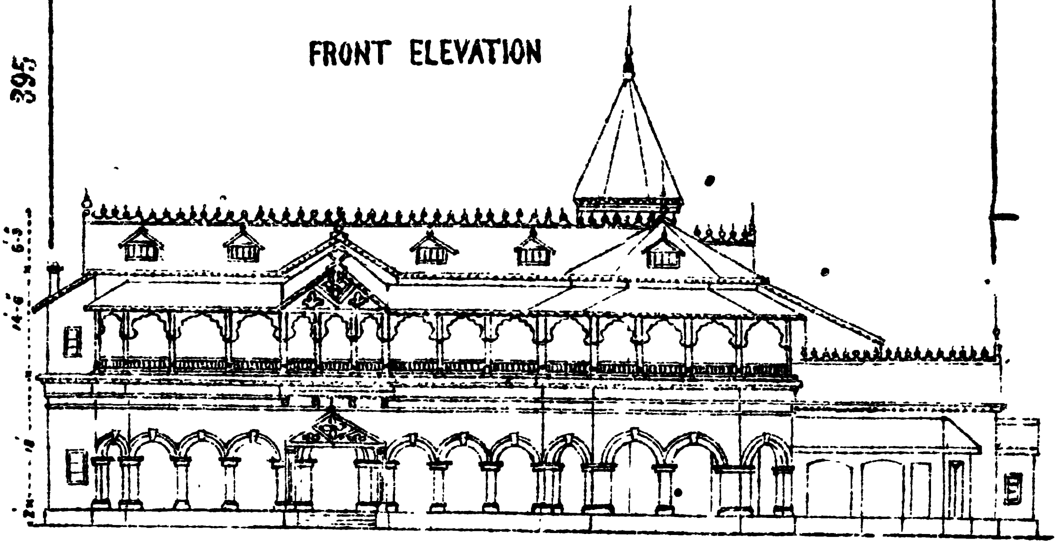
Scale 20' = 1"

PLAN No. 24.


17.0
15.8
17.0
VERANDAH
DINING ROOM 24' x 18'
PANTRY 14.9 x 12'
CHABUTARA
18.0
BED ROOM 12' x 15'
DRESSING ROOM 12' x 15'
BATH ROOM 12' x 9'
STORE ROOM
SITTING ROOM
BED ROOM
BATH ROOM 12' x 9'
VERANDA 12' x 8'
DRESSING ROOM
BATH ROOM
OFFICE 16' x 14'
60.0
133.9
24.0
SCALE, 25'=1."

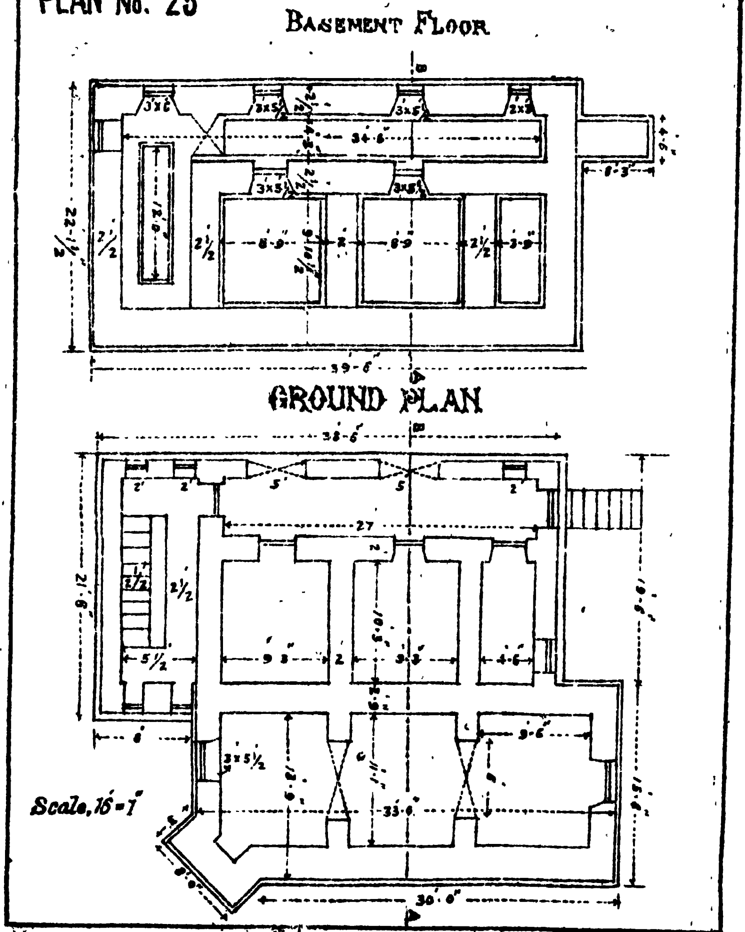
PLAN No. 24

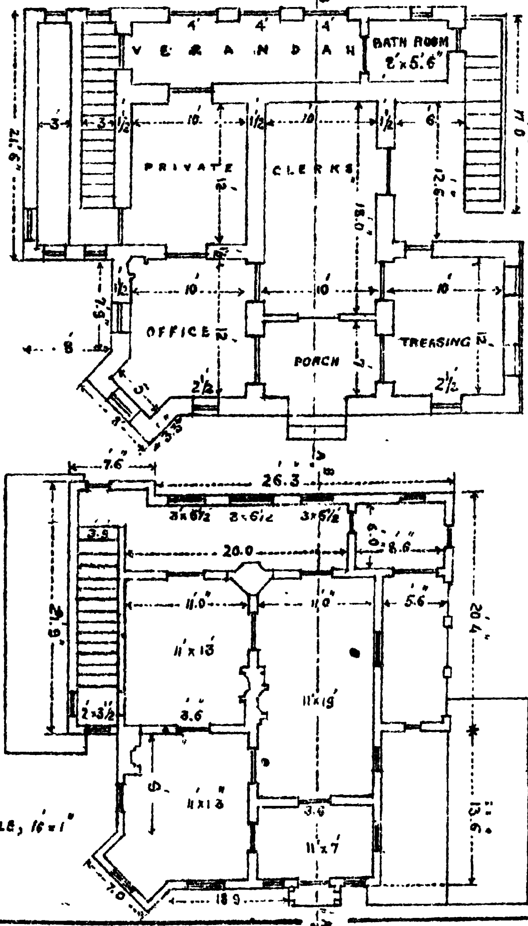
FRONT ELEVATION



Scale, 25' = 1"

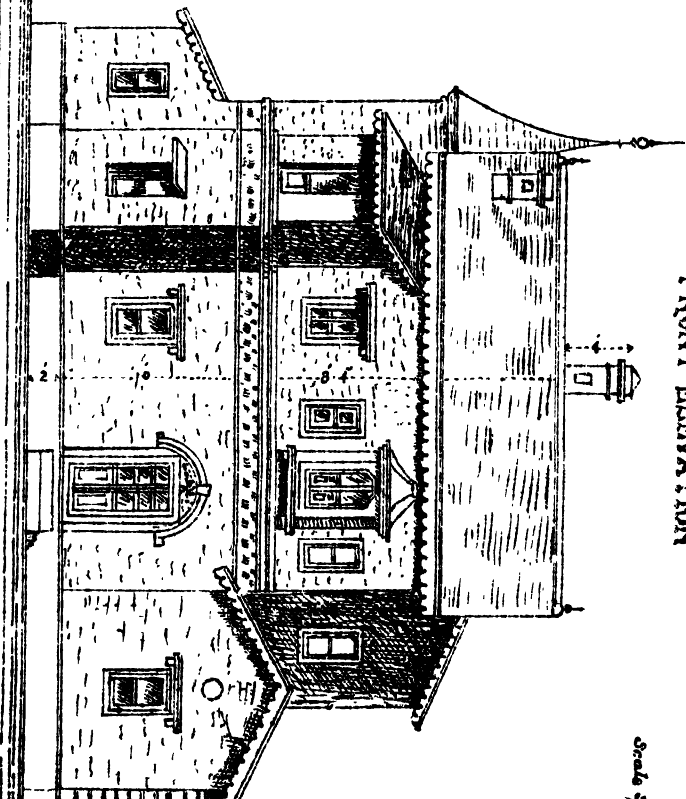
PLAN No. 25



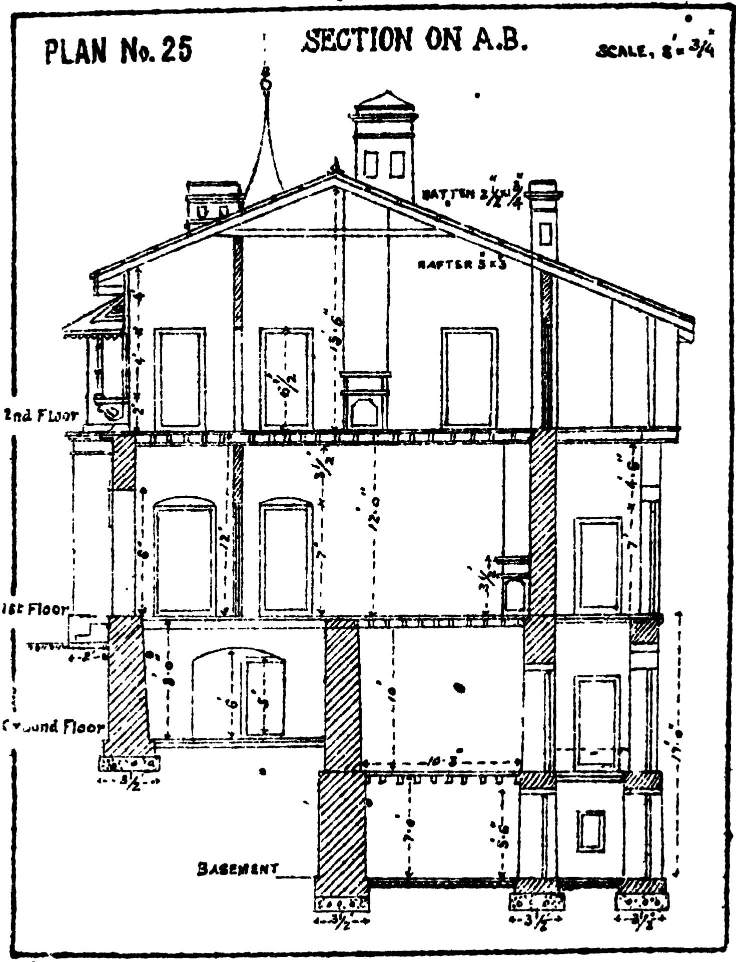


FIRST FLOOR PLAN No. 25 SECOND FLOOR

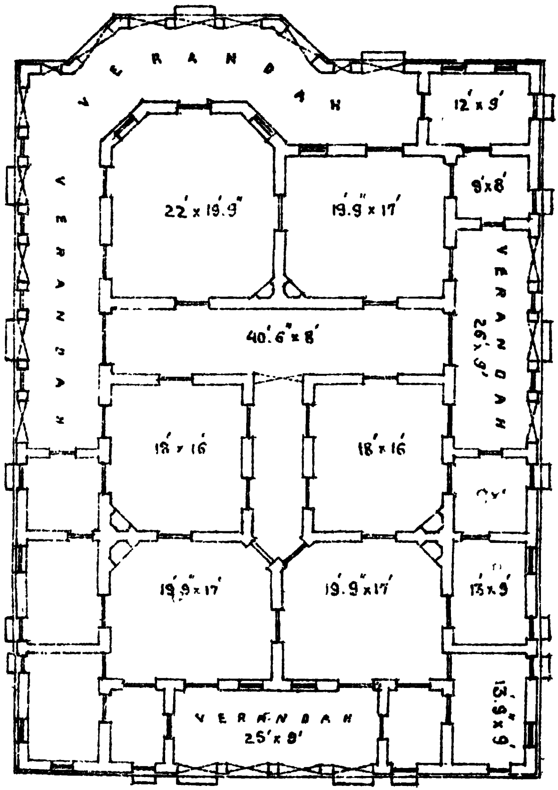
PLAN No. 25



FRONT ELEVATION

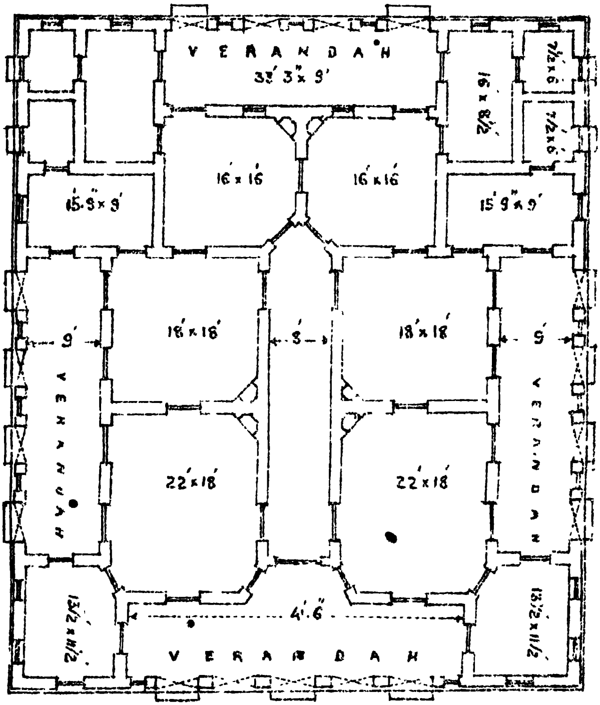

PLAN No. 25
SECTION ON A.B.
SCALE, 8' = 3/4"
BATTEN 2 1/2" x 3/4"
RAFTER 5" x 3"
2nd Floor
1st Floor
Ground Floor
BASEMENT

PLAN No. 26.



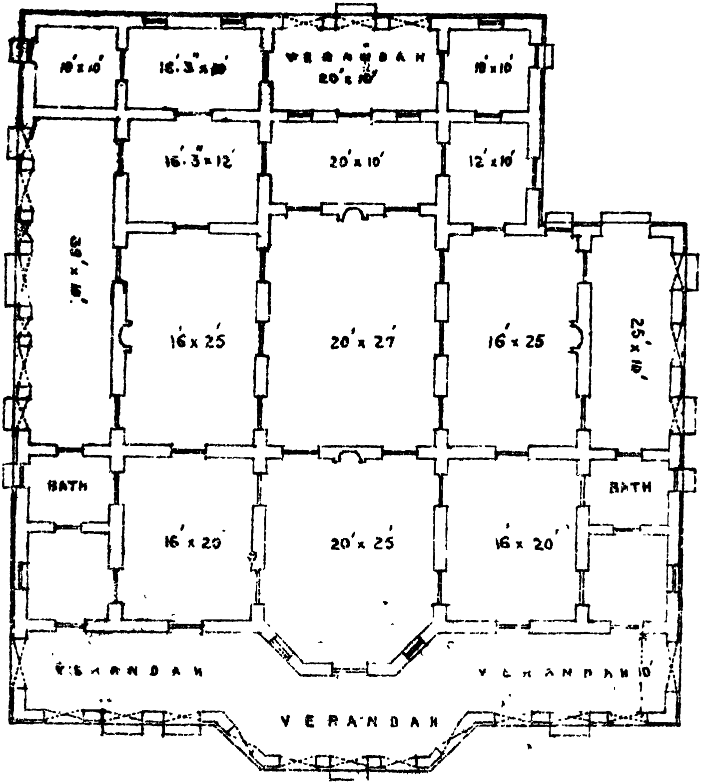
SCALE, 24' = 1"

PLAN No. 27.



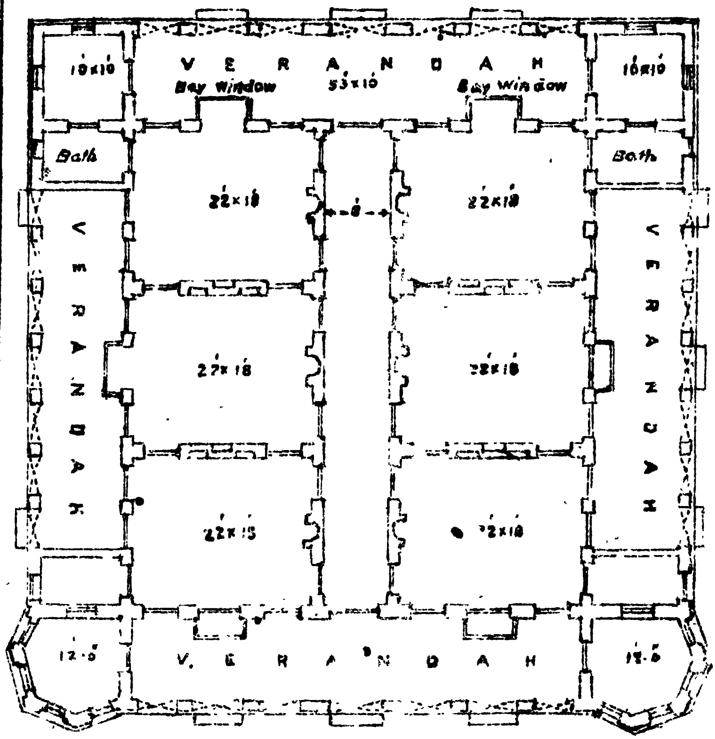
SCALE, 24' = 1"

PLAN No. 28.

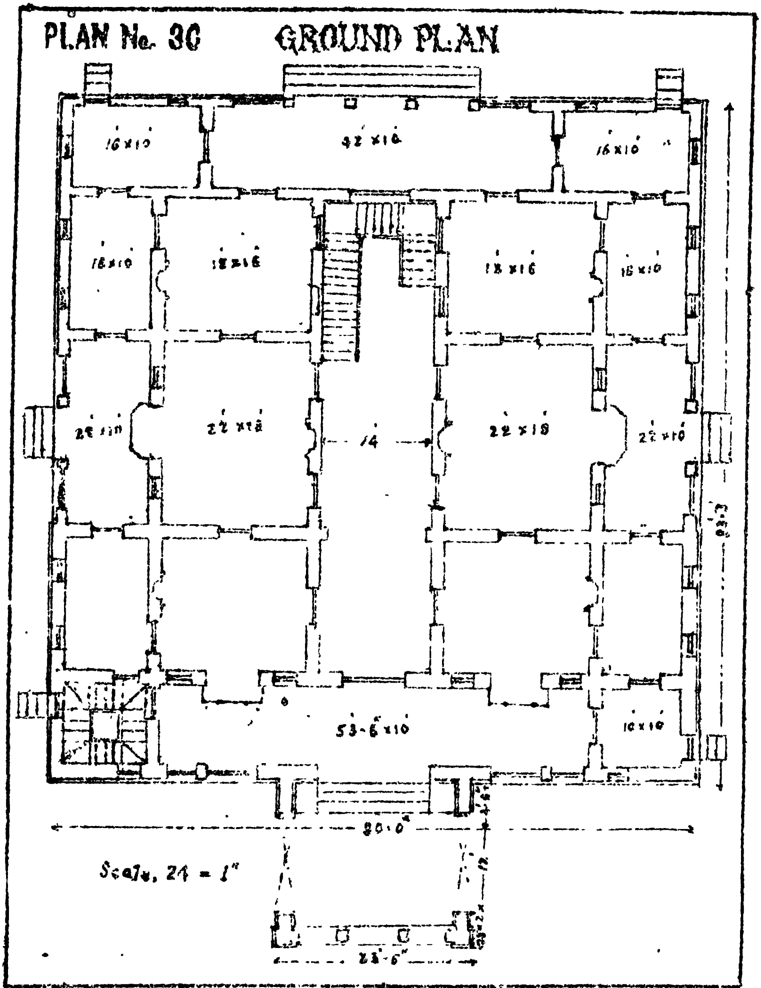


SCALE, 24' = 1"

PLAN No. 29.

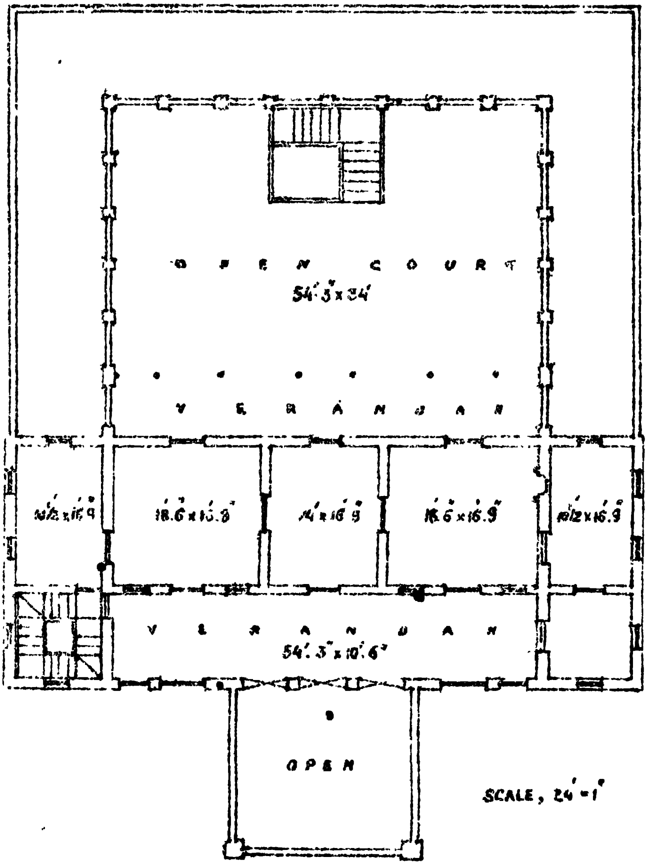


Scale, 24' = 1"

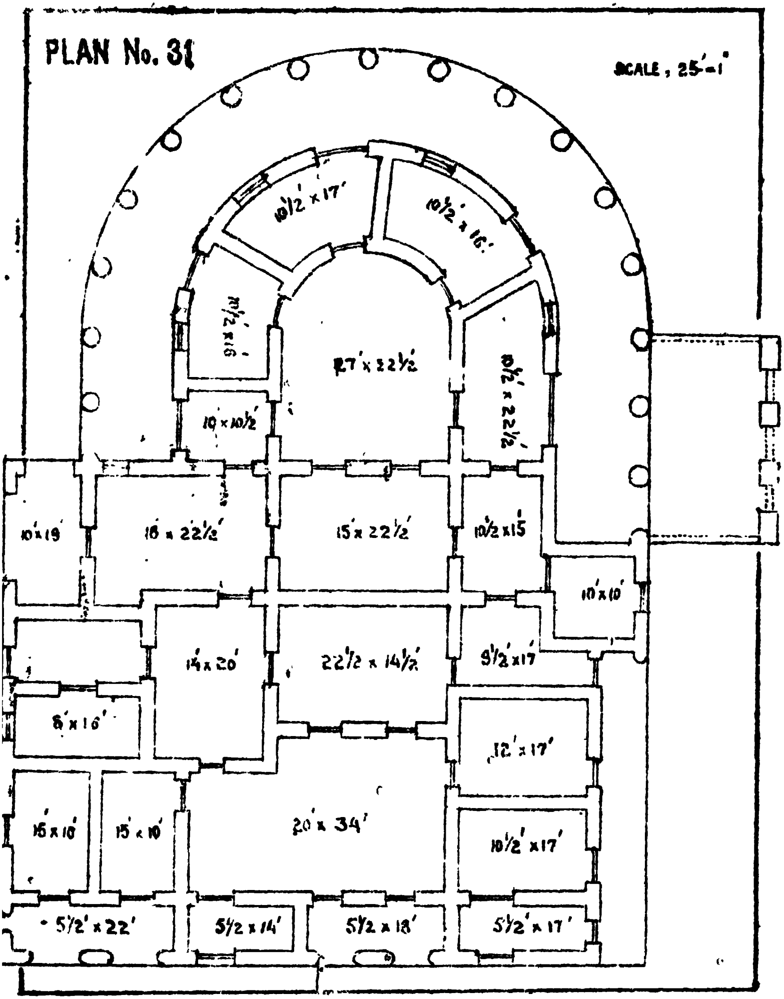

PLAN No. 30
GROUND PLAN
16 x 10
42 x 16
16 x 10
18 x 10
18 x 16
18 x 16
18 x 10
22 x 10
22 x 18
14
22 x 18
22 x 10
53-6 x 10
10 x 10
80-0
Scale, 24 = 1"
23-6

PLAN No. 80

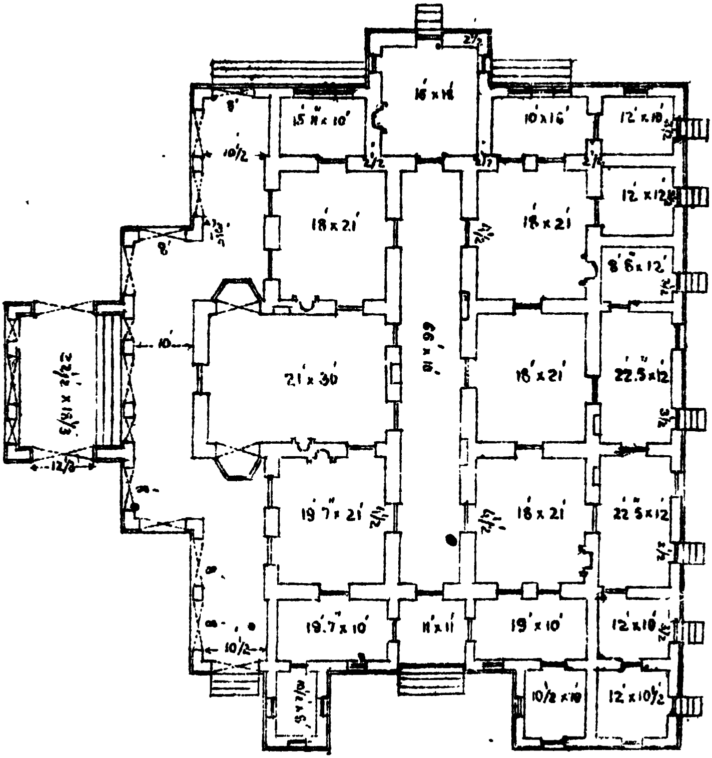
UPPER PLAN



SCALE, 24'=1"

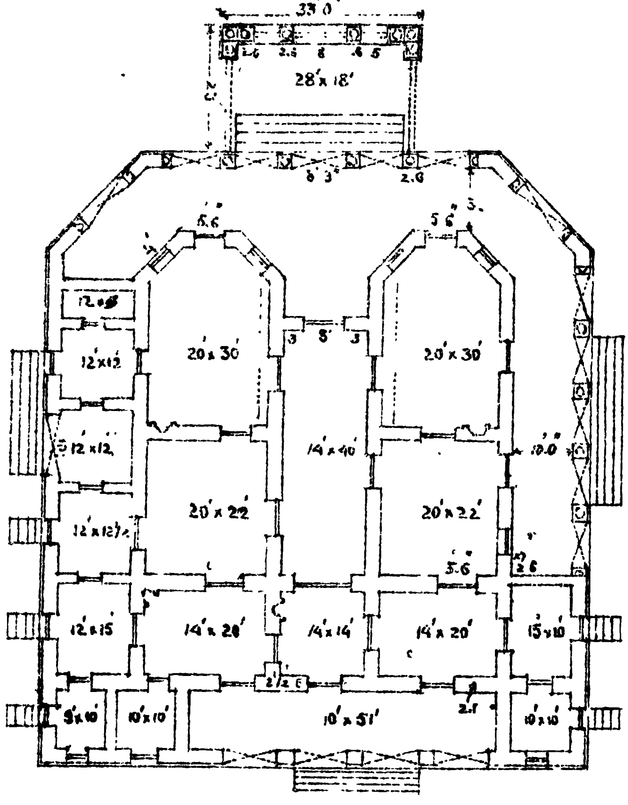

PLAN No. 31
SCALE: 25'=1"
10½' x 17'
10½' x 16'
10½' x 16'
27' x 22½'
10½' x 22½'
10 x 10½
10' x 19'
16 x 22½'
15' x 22½'
10½ x 15'
10' x 10'
14' x 20'
22½ x 14½'
9½' x 17'
8' x 16'
12' x 17'
16' x 10'
15' x 10'
20' x 34'
10½' x 17'
5½' x 22'
5½ x 14'
5½ x 18'
5½' x 17'

PLAN No. 32



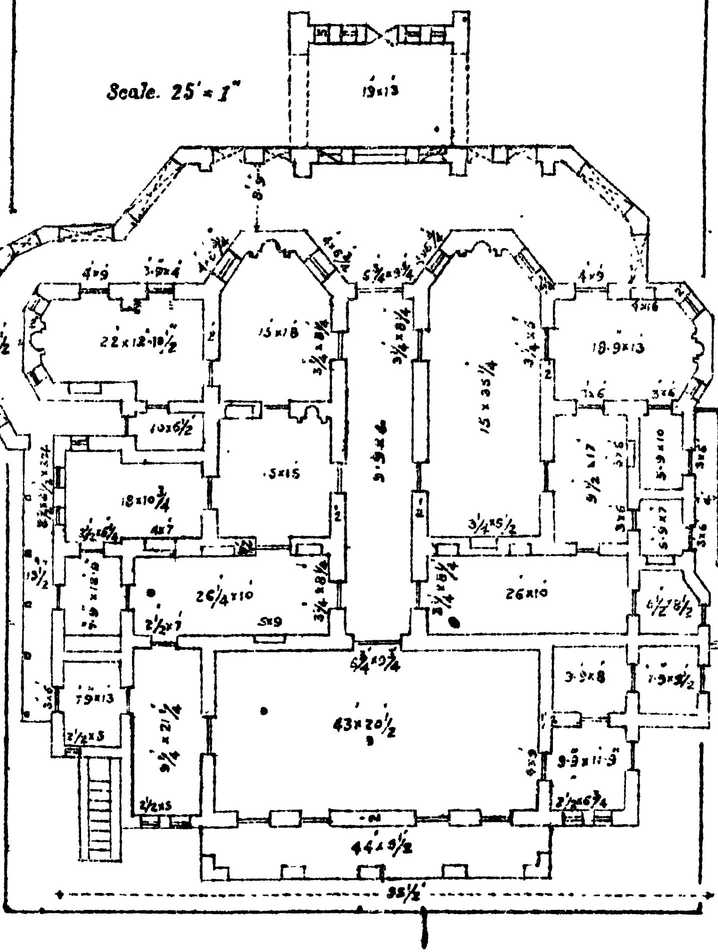
SCALE, 30'=1"

PLAN No. 33

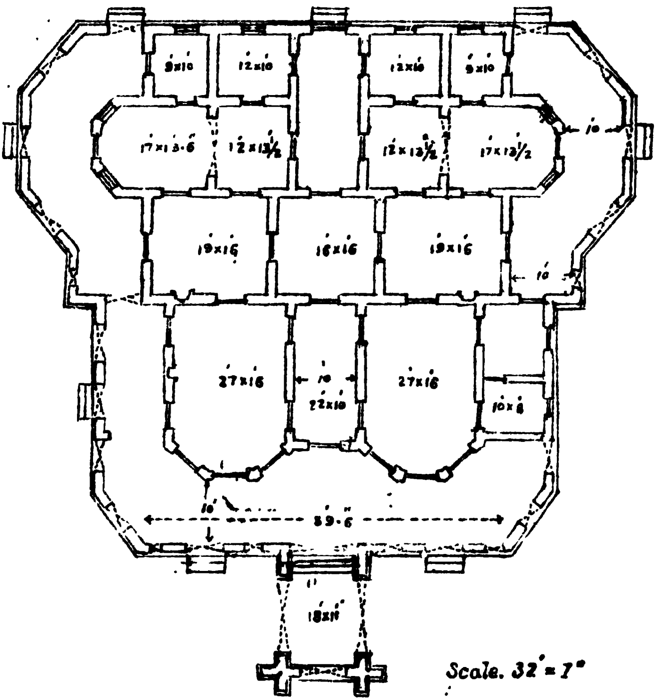


SCALE, 30'=1"

PLAN No 34

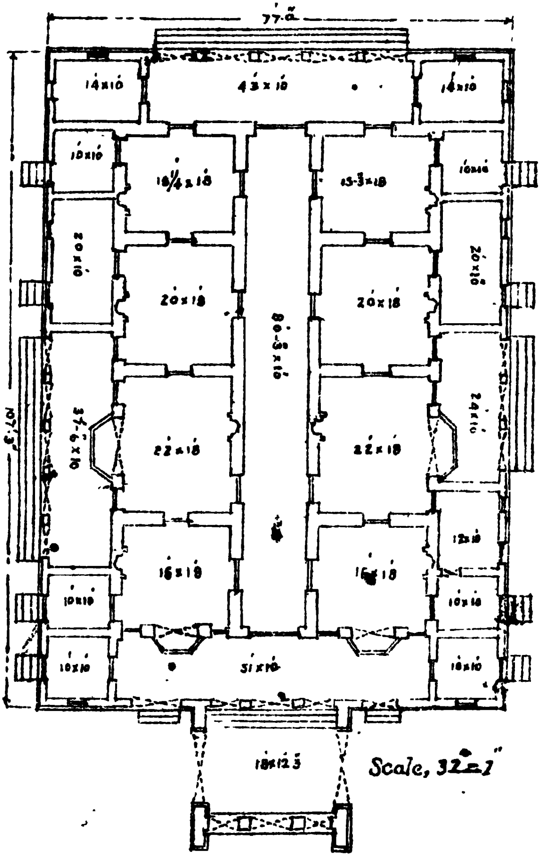


PLAN No. 35

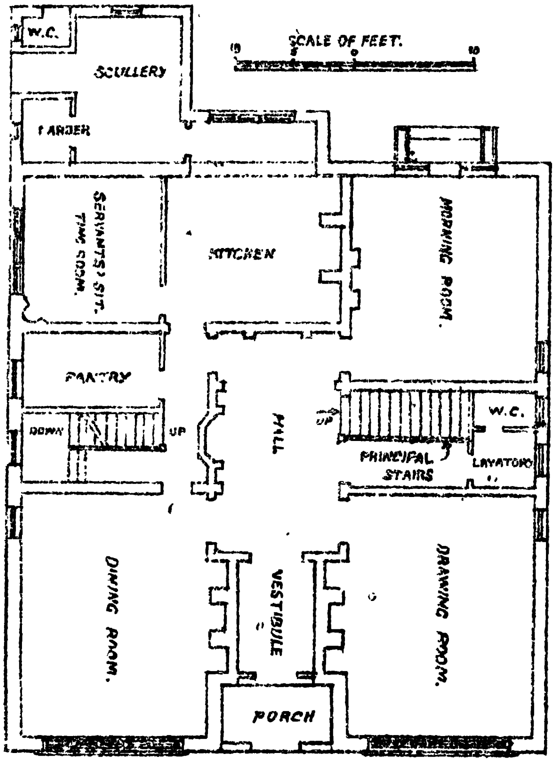


Scale. 32' = 1"

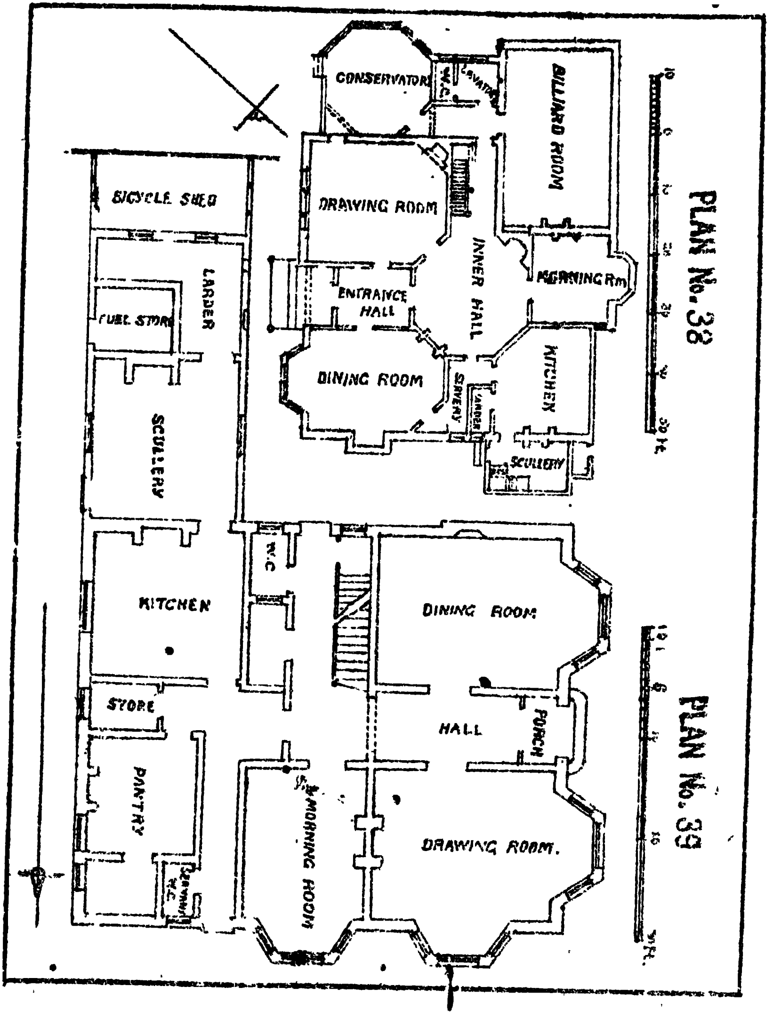
PLAN No. 36.

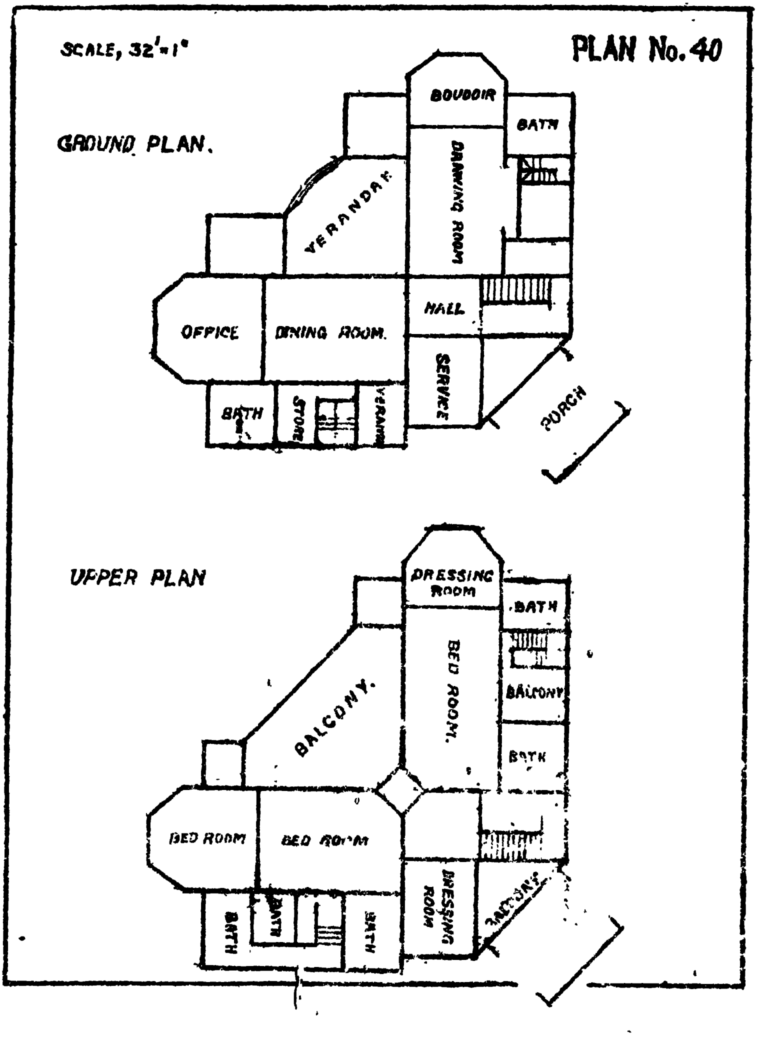

77-0"
14x10
43x10
14x10
10x10
16¼x18
15-3"x18
10x10
20x10
20x18
80-3x10
20x18
20x10
107-3"
37-6x10
22x18
22x18
24x10
12x10
16x18
16x18
10x10
10x10
10x10
51x10
10x10
18x12.3
Scale, 32=1"

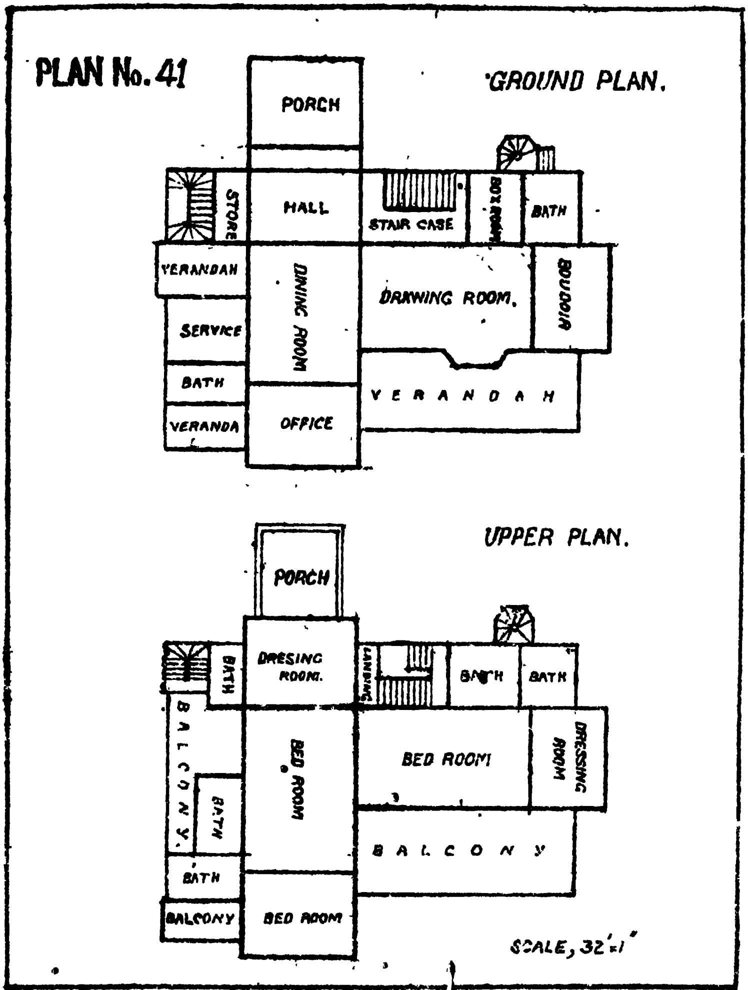
PLAN No: 37

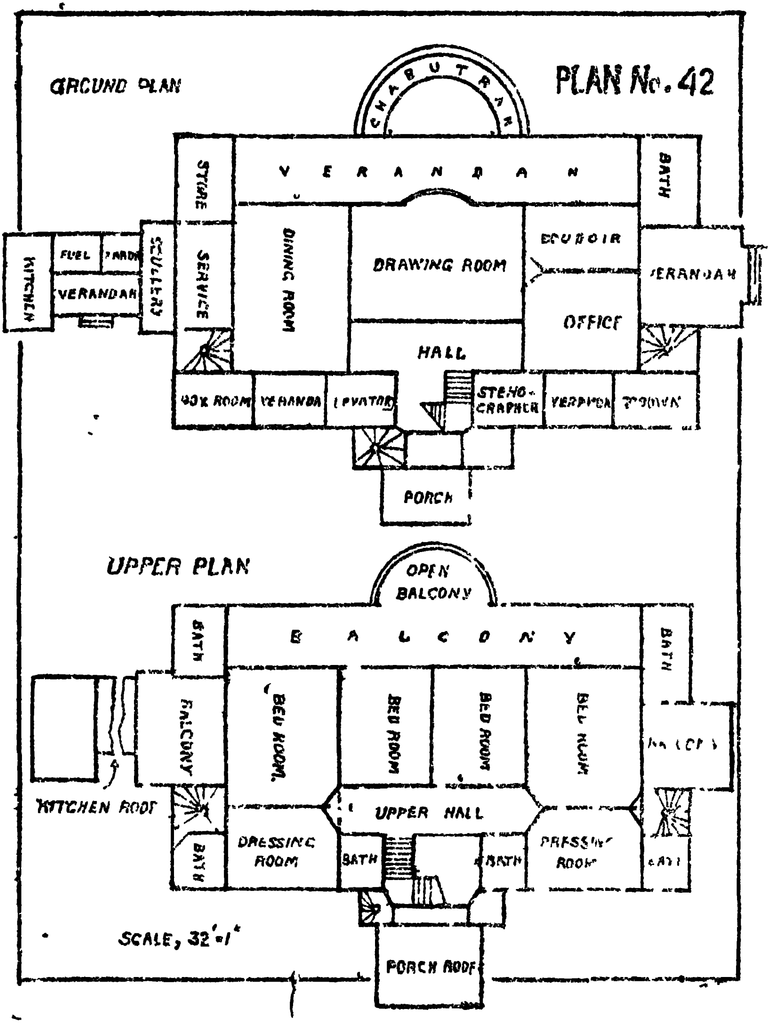


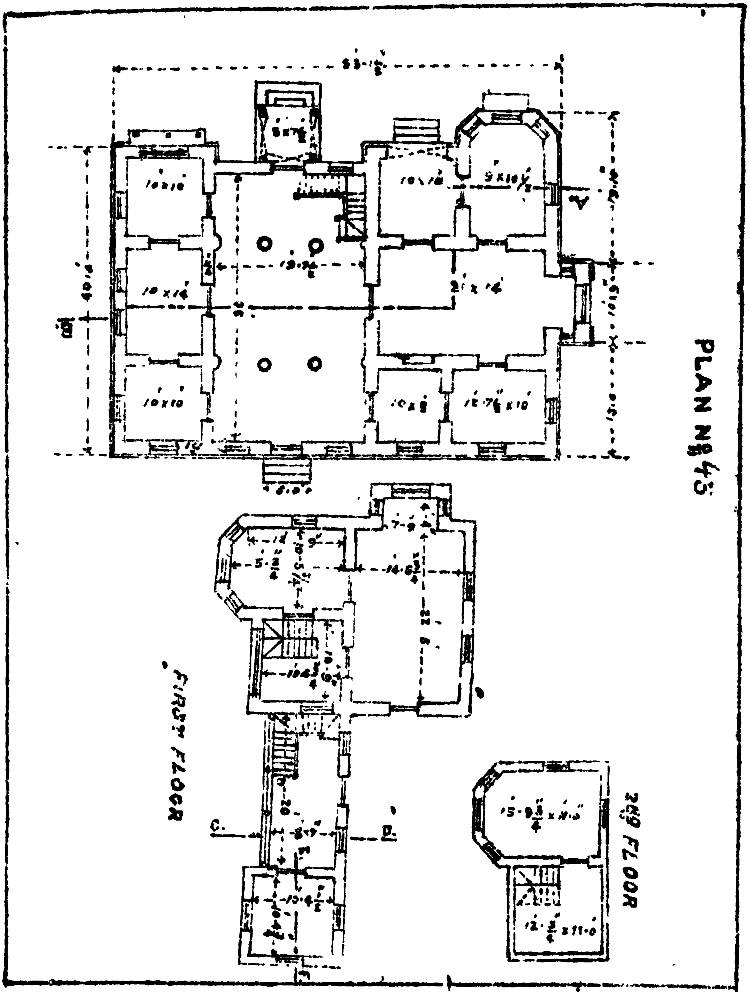
SCALE OF FEET.
W.C.
SCULLERY
LARDER
SERVANTS' SIT-TING ROOM.
KITCHEN
MORNING ROOM.
PANTRY
DOWN
UP
HALL
UP
W.C.
PRINCIPAL STAIRS
LAVATORY
DINING ROOM.
VESTIBULE
DRAWING ROOM.
PORCH


PLAN No. 38
CONSERVATORY
W.C.
LAVATORY
BILLIARD ROOM
DRAWING ROOM
INNER HALL
MORNING Rm
ENTRANCE HALL
DINING ROOM
SERVERY
LARDER
KITCHEN
SCULLERY
BICYCLE SHED
LARDER
FUEL STORE
SCULLERY
PLAN No. 39
W.C.
KITCHEN
DINING ROOM
HALL
PORCH
STORE
PANTRY
MORNING ROOM
DRAWING ROOM.


SCALE, 32' = 1"
PLAN No. 40
GROUND PLAN.
BOUDOIR
BATH
DRAWING ROOM
VERANDAH
HALL
OFFICE
DINING ROOM.
SERVICE
PORCH
BATH
STORE
UPPER PLAN
DRESSING ROOM
BATH
BED ROOM.
BALCONY.
BALCONY
BATH
BED ROOM
BED ROOM
DRESSING ROOM
BATH
BATH
BATH

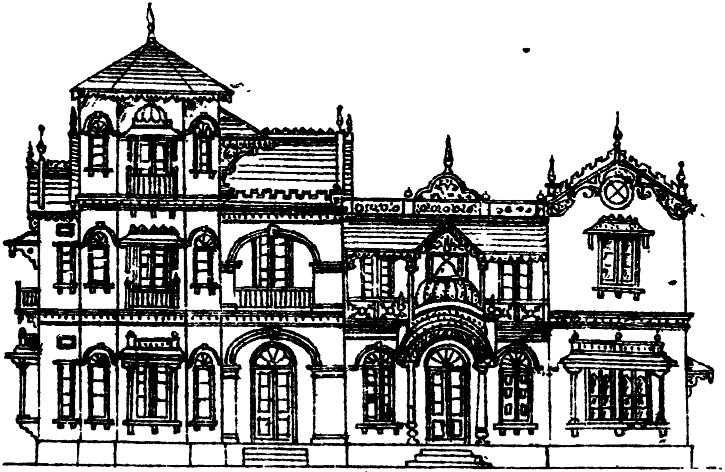

PLAN No. 41
GROUND PLAN.
PORCH
HALL
STORE
STAIR CASE
BOX ROOM
BATH
VERANDAH
DINING ROOM
DRAWING ROOM.
BOUDOIR
SERVICE
BATH
VERANDAH
VERANDA
OFFICE
UPPER PLAN.
PORCH
BATH
DRESING ROOM.
LANDING
BATH
BATH
BALCONY.
BED ROOM
BED ROOM
DRESSING ROOM
BATH
BATH
BALCONY
BALCONY
BED ROOM
SCALE, 32'=1"

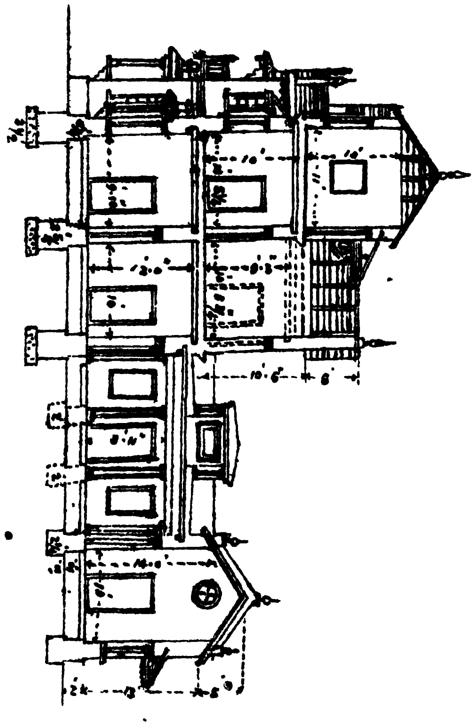

GROUND PLAN
PLAN No. 42
CHABUTRAH
VERANDAH
STORE
BATH
SERVICE
DINING ROOM
DRAWING ROOM
BOUDOIR
VERANDAH
OFFICE
KITCHEN
FUEL
VERANDAH
SCULLERY
HALL
VERANDA
STENO-
GRAPHER
PORCH
UPPER PLAN
OPEN
BALCONY
BALCONY
BATH
BALCONY
BED ROOM.
BED ROOM
BED ROOM
UPPER HALL
DRESSING
ROOM
BATH
KITCHEN ROOF
SCALE, 32'=1"
PORCH ROOF


PLAN No 43
FIRST FLOOR
2ND FLOOR

FLAN No. 43

FRONT ELEVATION

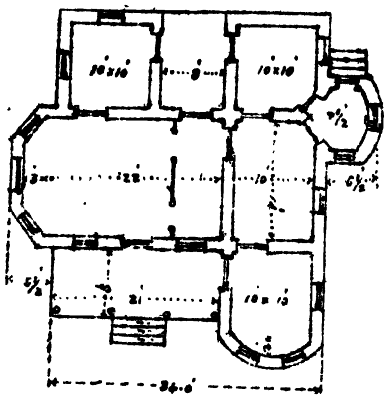




PLAN No. 43

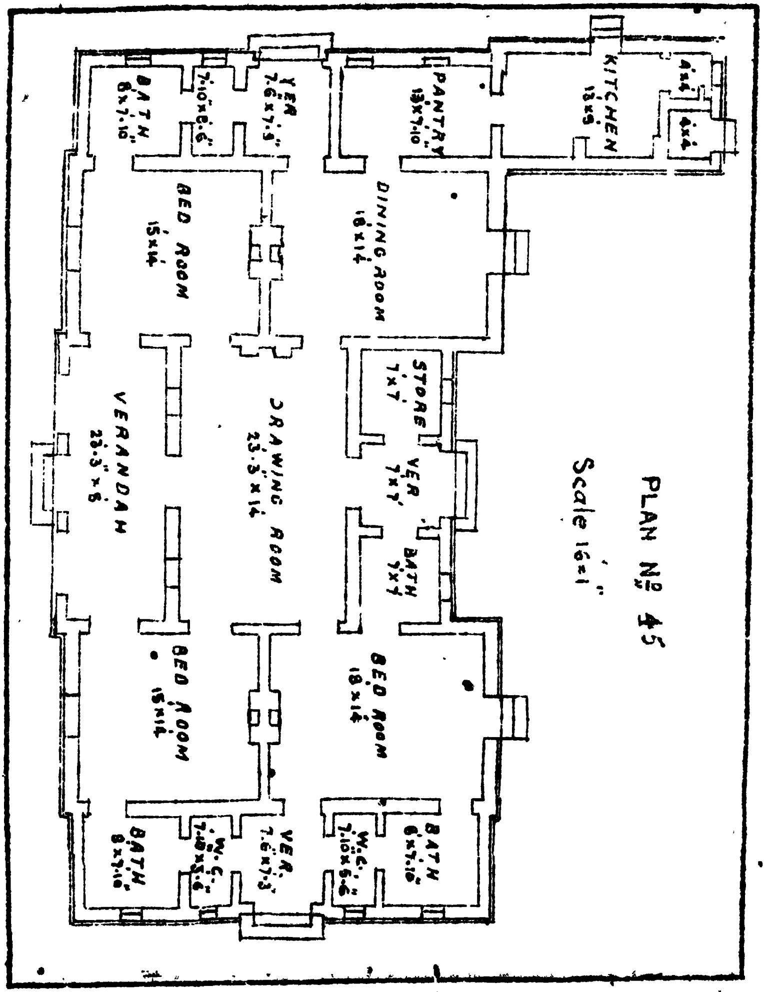
SECTION ON A.B.

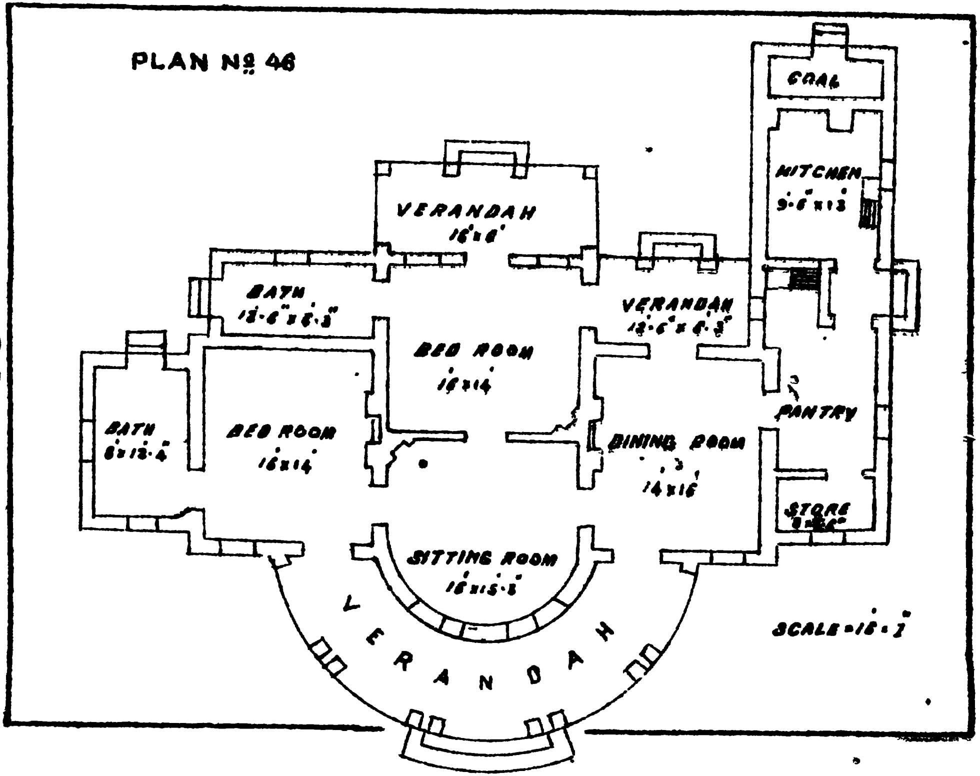
PLAN·No 44

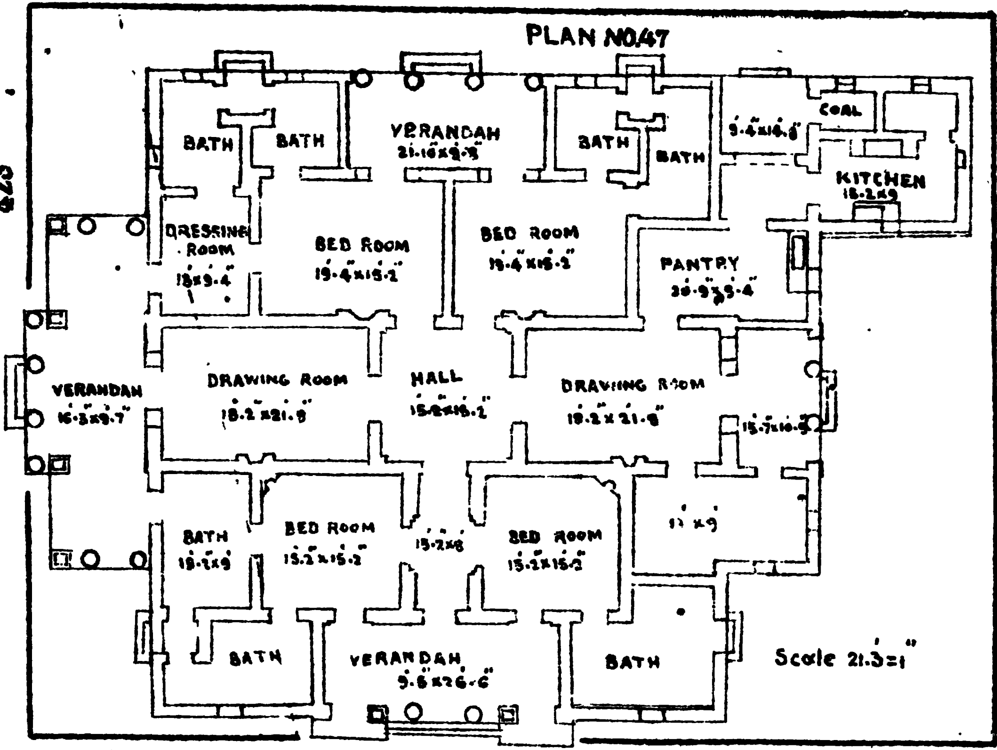


FRONT ELEVATION

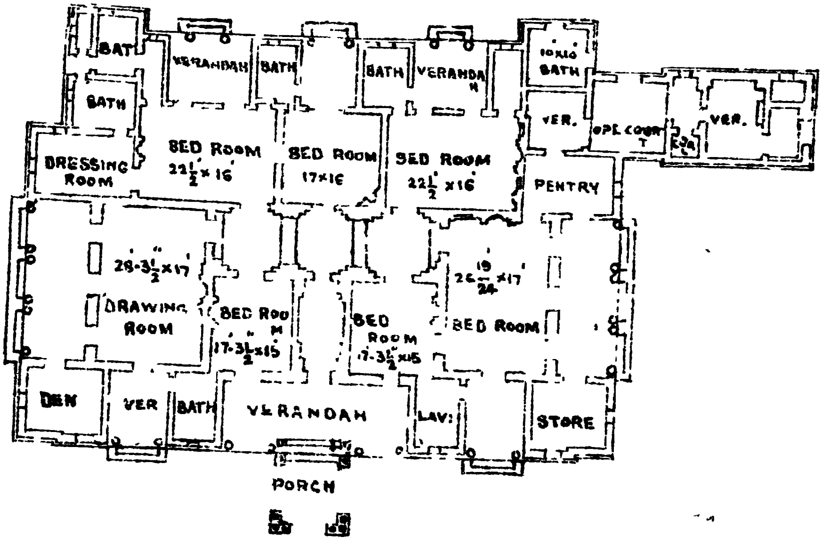



PLAN No 45
Scale 16=1"
BATH 8x7.10
7.10"x6.6"
VER 7.6x7.3"
PANTRY 13x7.10
KITCHEN 13x9
4x4
4x4
BED ROOM 15x14
DINING ROOM 18x14
VERANDAH 23.3"x8
DRAWING ROOM 23.3x14
STORE 7x7
VER 7x7
BATH 7x7
BED ROOM 15x14
BED ROOM 18x14
BATH 8x7.10"
W.C. 7.10x5.6"
VER 7.6x7.3"
W.C. 7.10x5.6"
BATH 8x7.10"


PLAN No. 46
COAL
KITCHEN
9·6" x 13'
VERANDAH
16' x 6'
BATH
12·6" x 6·3"
VERANDAH
12·6" x 6·3"
BED ROOM
16' x 14'
BATH
6' x 12·4"
BED ROOM
16' x 14'
PANTRY
DINING ROOM
14' x 16'
STORE
SITTING ROOM
16' x 15·3"
VERANDAH
SCALE = 16' = 1"

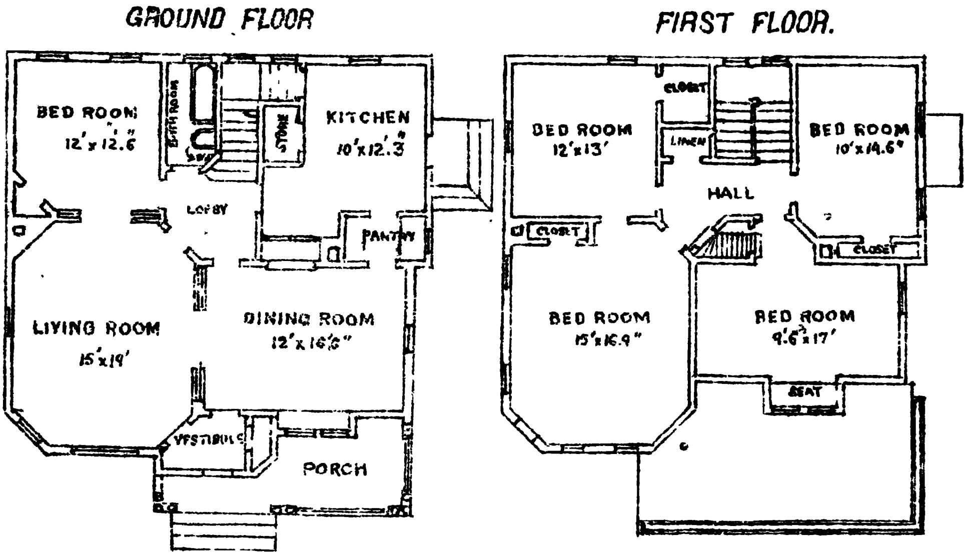

PLAN NO.47
BATH
BATH
VERANDAH 21·16 x 9·9
BATH
BATH
COAL 9·4 x 14·8
KITCHEN 18·2 x 9
DRESSING ROOM 18 x 9·4
BED ROOM 19·4 x 15·2
BED ROOM 19·4 x 15·2
PANTRY 20·9 x 5·4
VERANDAH 16·3 x 9·7
DRAWING ROOM 18·2 x 21·8
HALL 15·2 x 18·2
DRAWING ROOM 18·2 x 21·8
15·7 x 10·5
BATH 19·2 x 9
BED ROOM 15·2 x 15·2
15·2 x 8
BED ROOM 15·2 x 15·2
11 x 9
BATH
VERANDAH 9·6 x 26·6
BATH
Scale 21·3=1"

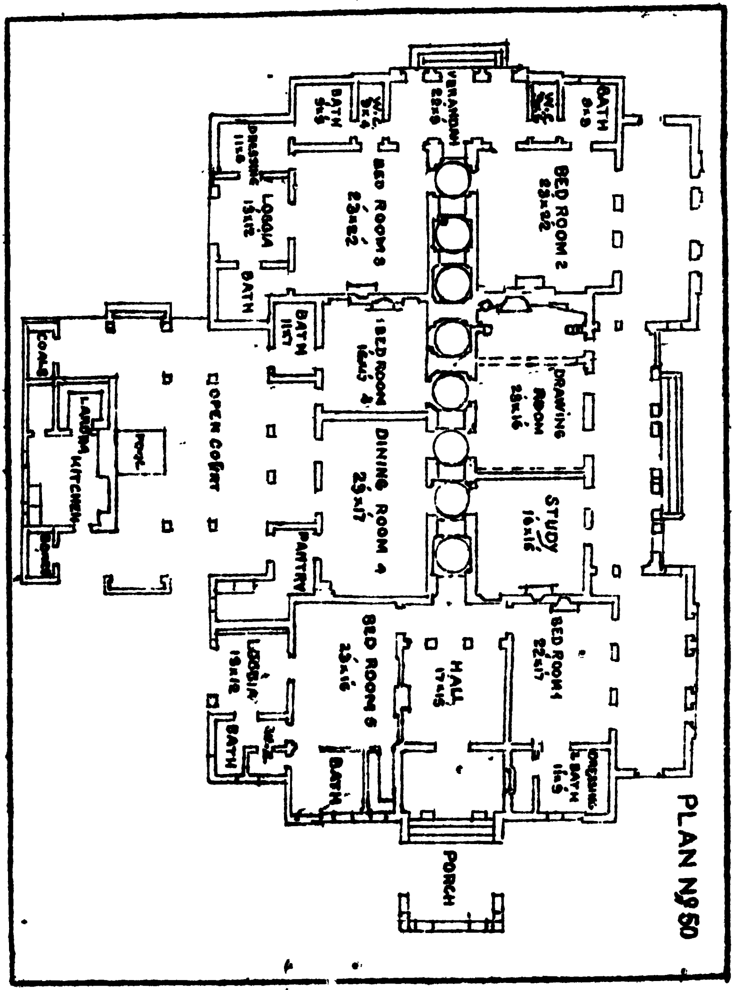
PLAN No. 48

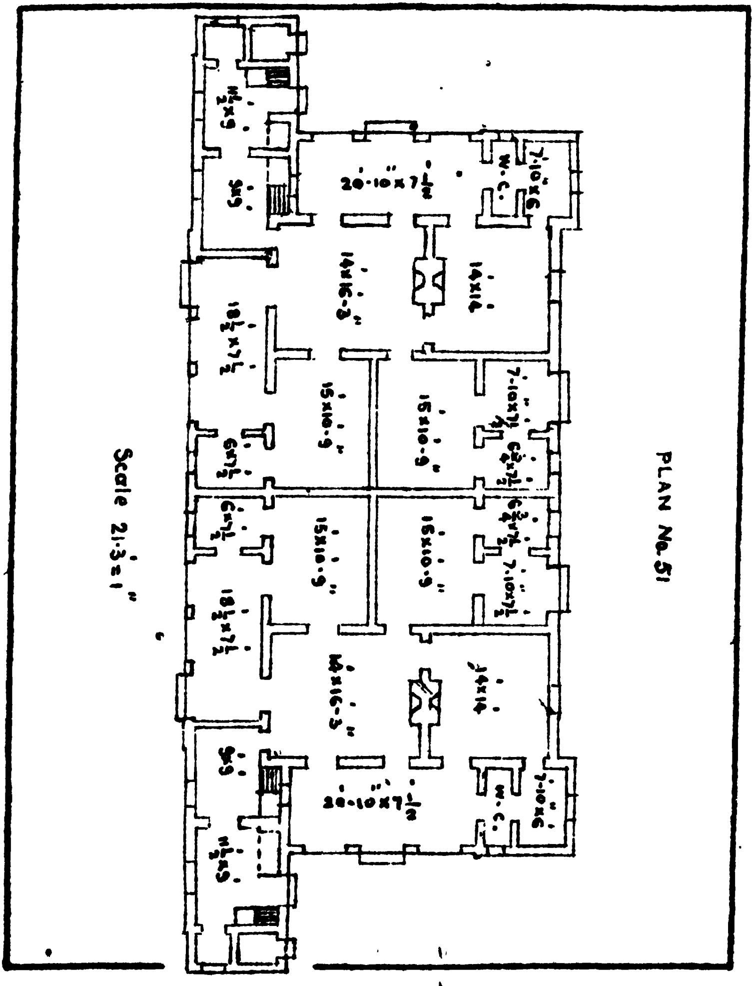

BAT
VERANDAH
BATH
BATH
VERANDAH
10x10
BATH
BATH
VER.
OPL. COURT
VER.
DRESSING ROOM
BED ROOM
22½ x 16
BED ROOM
17x16
BED ROOM
22½ x 16
PENTRY
28-3½ x 17
DRAWING ROOM
BED ROOM
17-3½ x 15
BED ROOM
17-3½ x 15
26 19/24 x 17
BED ROOM
DEN
VER
BATH
VERANDAH
LAV:
STORE
PORCH

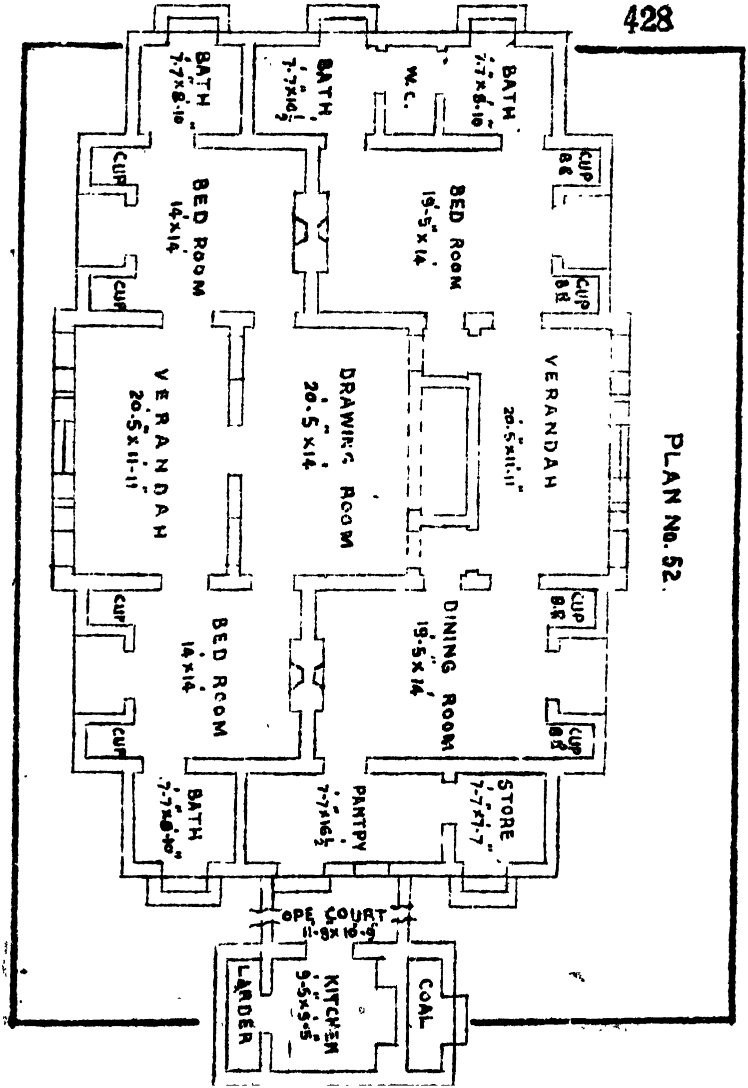
PLAN No. 49

SCALE, 1-16 INCH TO FOOT.

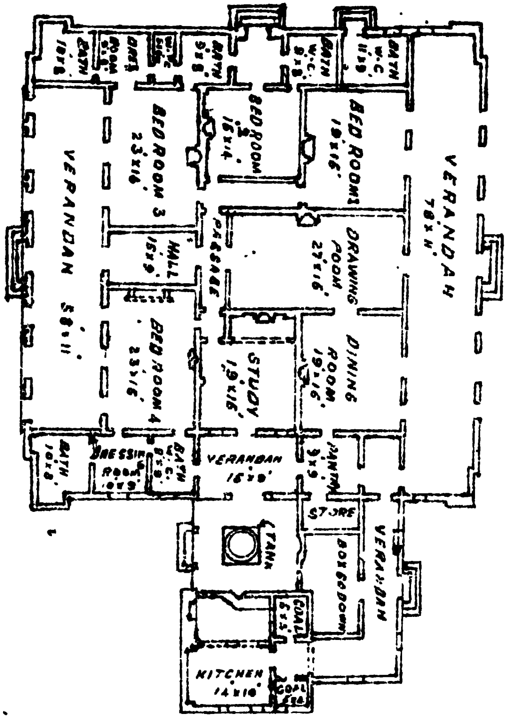



PLAN No 50
PORCH
HALL 17x15
BED ROOM 1 22x17
BED ROOM 5 23x16
DINING ROOM 4 23x17
STUDY 16x16
DRAWING ROOM 23x16
BED ROOM 2
BED ROOM 3
VERANDAH
LOGGIA
OPEN COURT
KITCHEN
PANTRY
BATH
W.C.
COALS


PLAN No. 51
Scale 21'-3" = 1"
W. C.
W. C.

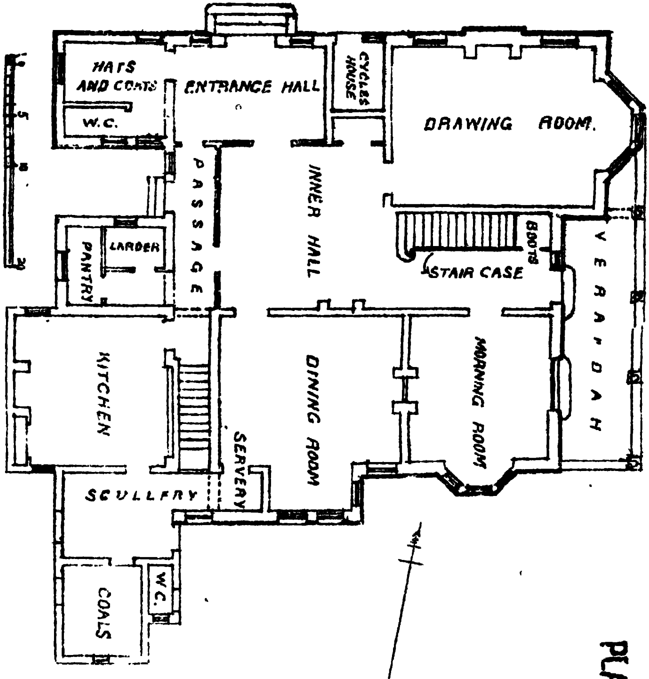

BATH 7-7x8-10
BATH 7-7x16½
W.C.
BATH 7-7x8-10
CUP
CUP 8.8
BED ROOM 14x14
BED ROOM 19-5x14
CUP
CUP 8.8
VERANDAH 20-5x11-11
DRAWING ROOM 20-5x14
VERANDAH 20-5x11-11
CUP
CUP 8.8
BED ROOM 14x14
DINING ROOM 19-5x14
CUP
CUP 8.8
BATH 7-7x8-10
PANTRY 7-7x16½
STORE 7-7x7-7
OPE COURT 11-8x16-9
LARDER
KITCHEN 9-5x9-5
COAL

PLAN No. 52.



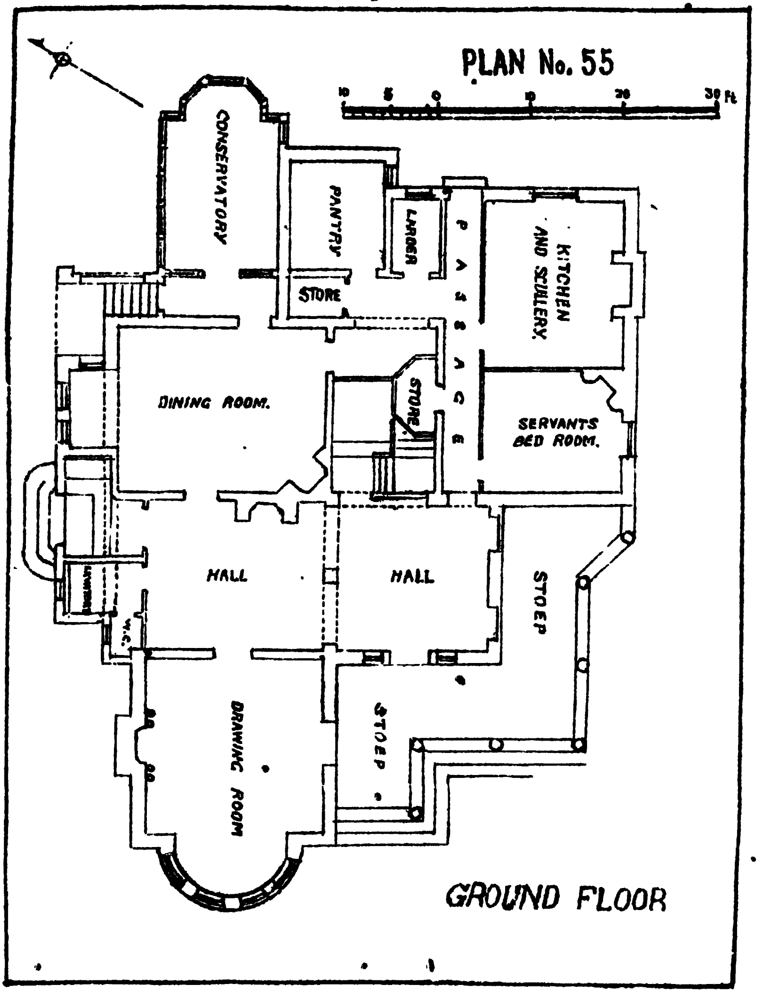
PLAN No. 53

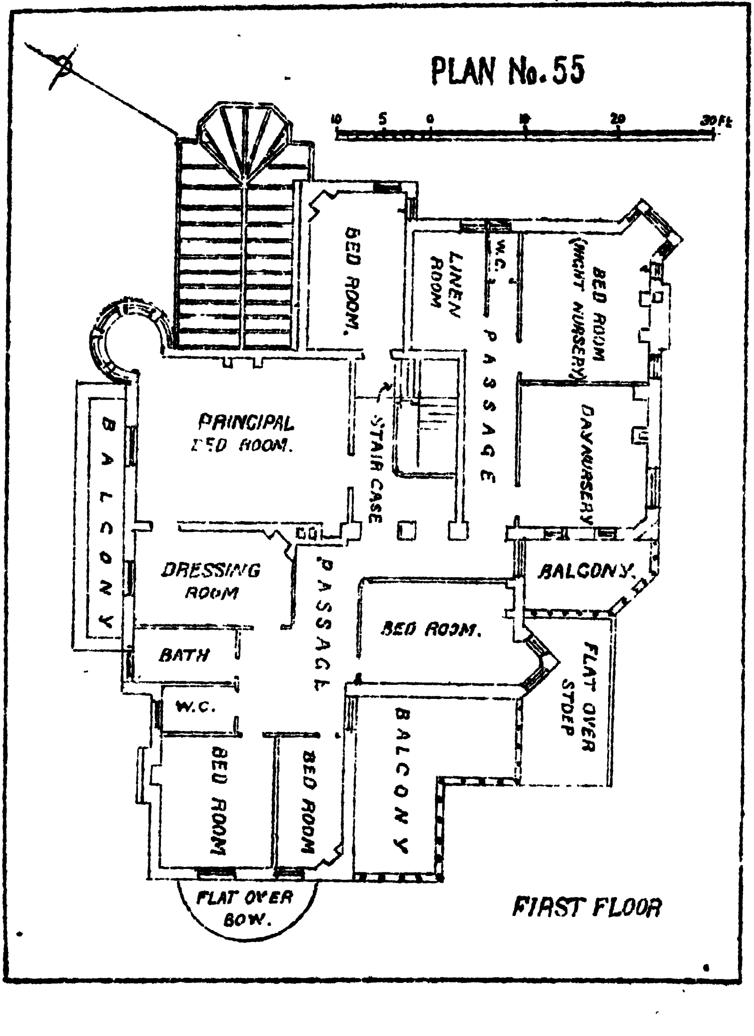
SCALE = 15 = 1 INCH



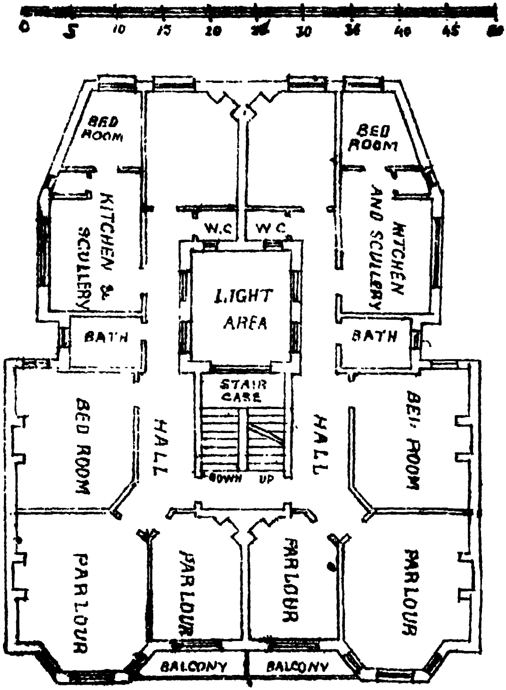
HATS AND COATS
ENTRANCE HALL
CYCLES HOUSE
DRAWING ROOM.
W.C.
PASSAGE
INNER HALL
LARDER
PANTRY
BOOTS
STAIR CASE
VERANDAH
KITCHEN
DINING ROOM
MORNING ROOM
SERVERY
SCULLERY
W.C.
COALS
5
8
20

PLAN No. 54


PLAN No. 55
10 5 0 10 20 30 Ft.
CONSERVATORY
PANTRY
LARDER
STORE
PASSAGE
KITCHEN AND SCULLERY
DINING ROOM.
STORE
SERVANTS BED ROOM.
HALL
HALL
STOEP
W.C.
DRAWING ROOM
STOEP
GROUND FLOOR


PLAN No. 55
10 5 0 10 20 30 Ft
BED ROOM.
LINEN ROOM
W.C.
BED ROOM (NIGHT NURSERY)
PASSAGE
PRINCIPAL BED ROOM.
STAIR CASE
DAY NURSERY
BALCONY
DRESSING ROOM
PASSAGE
BALCONY.
BED ROOM.
BATH
FLAT OVER STOEP
W.C.
BED ROOM
BED ROOM
BALCONY
FLAT OVER BOW.
FIRST FLOOR

PLAN No. 56.

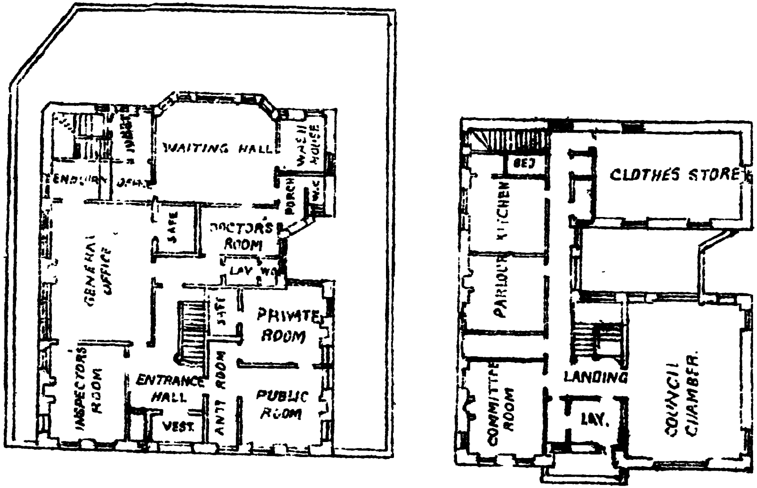

0 5 10 15 20 25 30 35 40 45 50
BED ROOM
BED ROOM
KITCHEN & SCULLERY
KITCHEN AND SCULLERY
W.C
W.C
LIGHT AREA
BATH
BATH
STAIR CASE
DOWN UP
HALL
HALL
BED ROOM
BED ROOM
PARLOUR
PARLOUR
PARLOUR
PARLOUR
BALCONY
BALCONY

PLAN No. 57

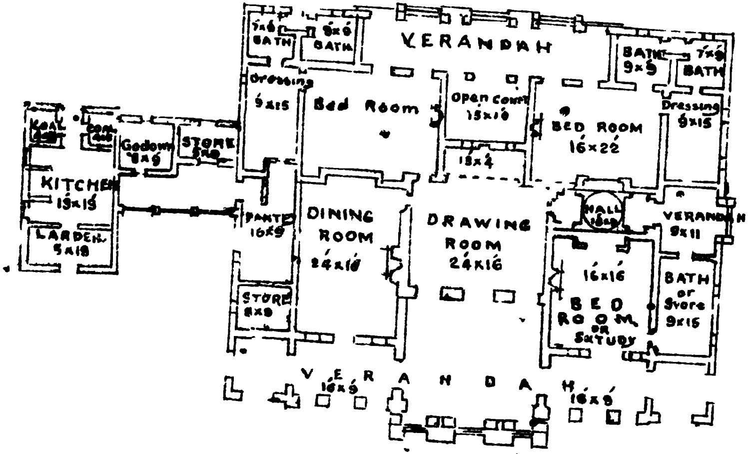
SCALE 32 = 1 INCH.

GROUND FLOOR

FIRST FLOOR.

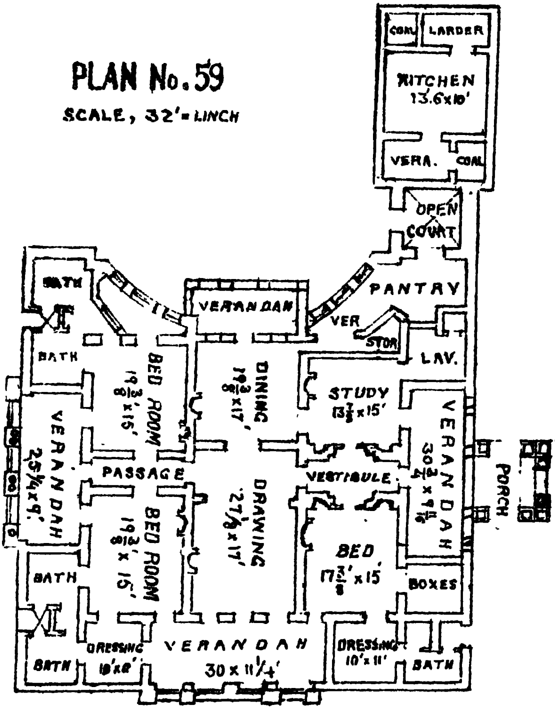


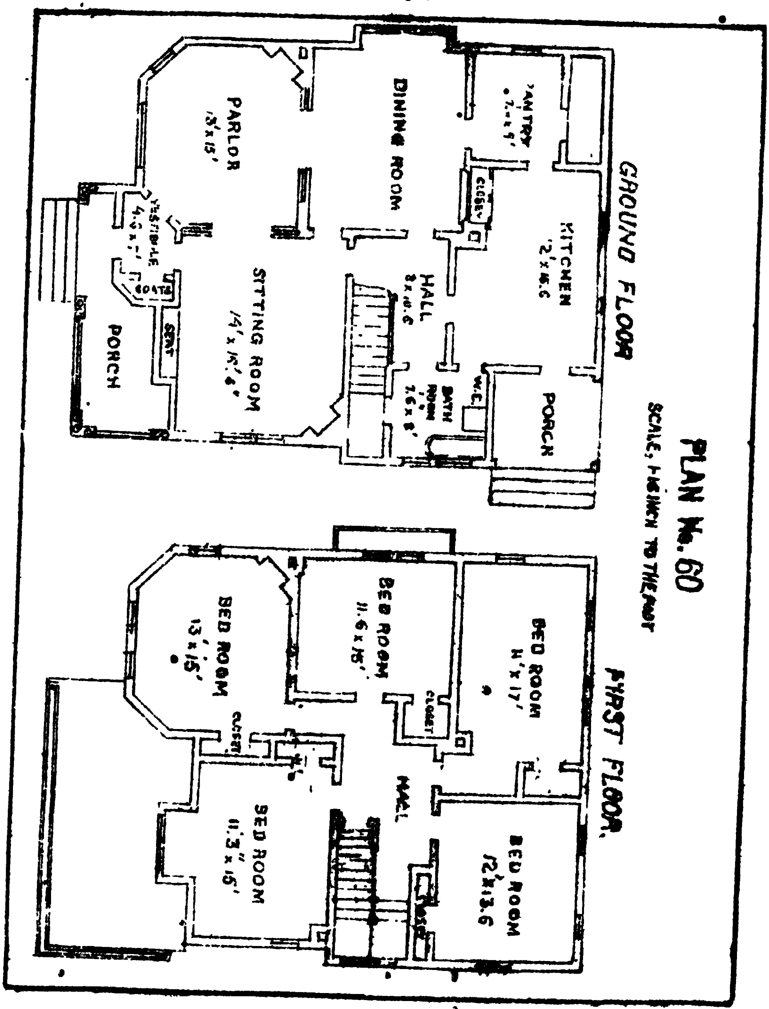
PLAN No 58


VERANDAH
7x6 BATH
9x6 BATH
Dressing 9x15
Bed Room
Open Court 15x16
15x4
BED ROOM 16x22
BATH 9x9
7x9 BATH
Dressing 9x15
KOAL
KITCHEN 19x19
LARDER 5x18
Godown 8x9
STORE
PANTRY 16x9
STORE 8x9
DINING ROOM 24x16
DRAWING ROOM 24x16
HALL
VERANDAH 9x11
16x16
BED ROOM OR STUDY
BATH or Store 9x15
VERANDAH
16x9
16x9

PLAN No. 59

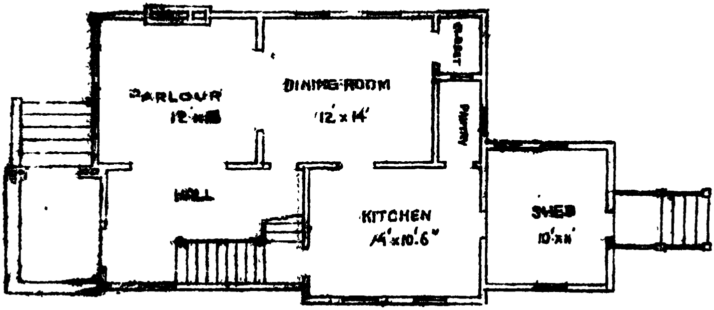
SCALE, 32' = 1 INCH



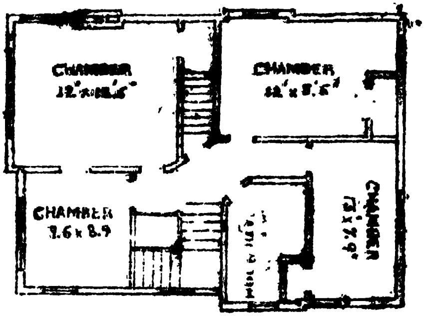

PLAN No. 60
SCALE, 1/16 INCH TO THE FOOT
GROUND FLOOR
PARLOR
13'x15'
DINING ROOM
PANTRY
CLOSET
KITCHEN
12'x16.6
VESTIBULE
4.6x7'
COATS
SEAT
PORCH
SITTING ROOM
14'x15'6"
HALL
8'x16.6
BATH ROOM
7.6x8'
W.C.
PORCH
FIRST FLOOR
BED ROOM
13'x15'
BED ROOM
11.6x15'
BED ROOM
11'x17'
CLOSET
CLOSET
HALL
BED ROOM
11.3"x15'
BED ROOM
12'x13.6
CLOSET

PLAN No. 61

SCALE, 1/16 INCH TO THE FOOT



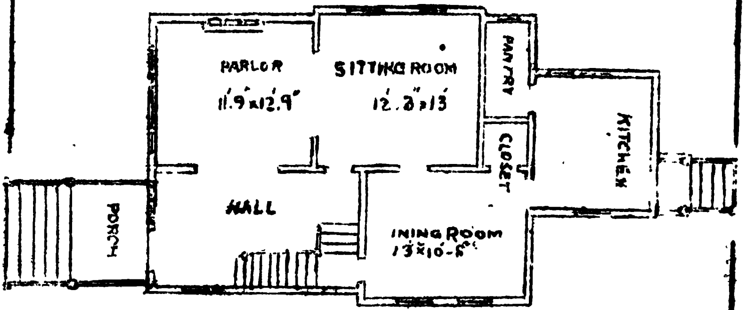
GROUND FLOOR.



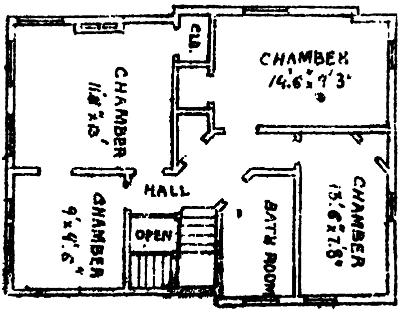
FIRST FLOOR.

PLAN No. 62

SCALE, 1-16 INCH TO THE FOOT.



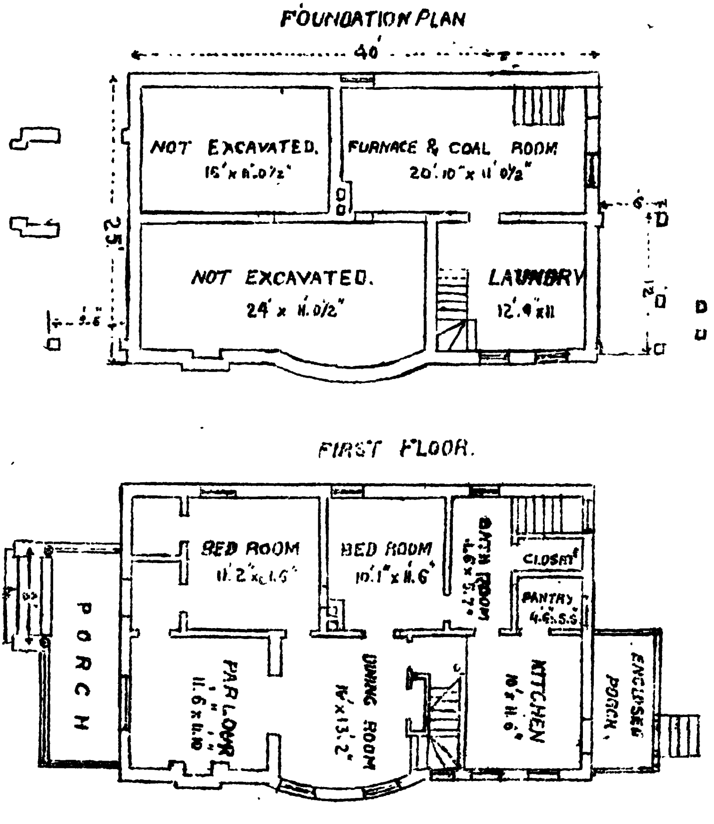
GROUND FLOOR.

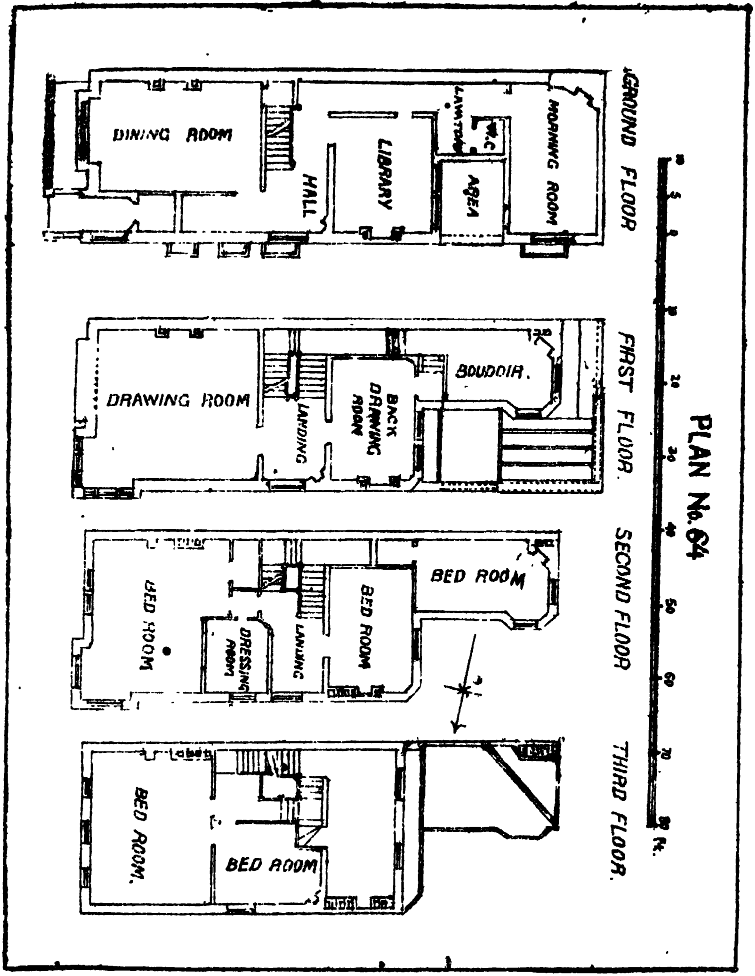


FIRST FLOOR.

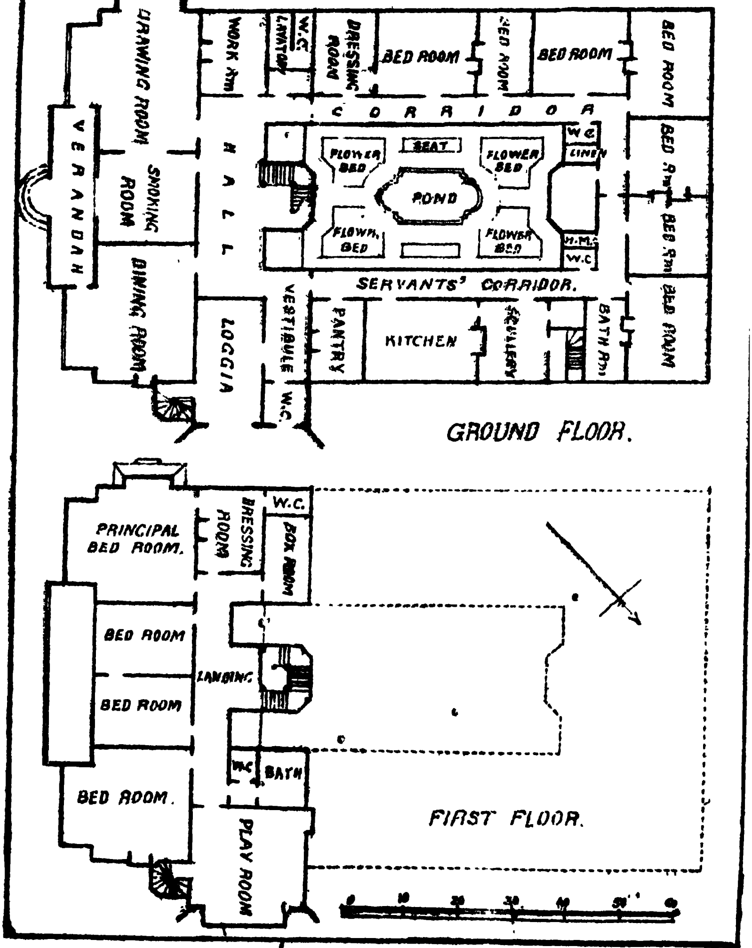
PLAN No. 63

SCALE, 1-16 INCH TO THE FOOT.




PLAN No. 64
GROUND FLOOR
DINING ROOM
HALL
LIBRARY
LAVATORY
W.C.
AREA
MORNING ROOM
FIRST FLOOR
DRAWING ROOM
LANDING
BACK DRAWING ROOM
BOUDOIR.
SECOND FLOOR
BED ROOM
DRESSING ROOM
LANDING
BED ROOM
BED ROOM
THIRD FLOOR
BED ROOM.
BED ROOM
FT.

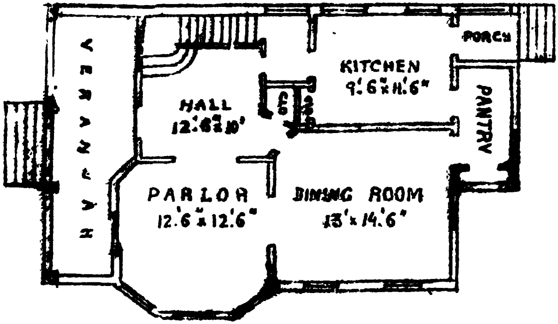
PLAN No. 65


DRAWING ROOM
WORK Rm
LAVATORY
W.C.
DRESSING ROOM
BED ROOM
BED ROOM
BED ROOM
BED ROOM
CORRIDOR
VERANDAH
SMOKING ROOM
HALL
FLOWER BED
SEAT
FLOWER BED
POND
FLOWER BED
FLOWER BED
W.C.
LINEN
H.M.
W.C.
BED Rm
BED Rm
SERVANTS' CORRIDOR.
DINING ROOM
LOGGIA
VESTIBULE
W.C.
PANTRY
KITCHEN
SCULLERY
BATH Rm
BED ROOM
GROUND FLOOR.
PRINCIPAL BED ROOM.
DRESSING ROOM
W.C.
BOX ROOM
BED ROOM
LANDING
BED ROOM
W.C.
BATH
BED ROOM.
PLAY ROOM
FIRST FLOOR.
0
10
20
30
40
50
60

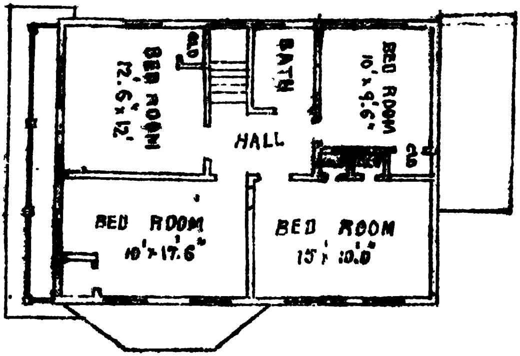
PLAN No. 66

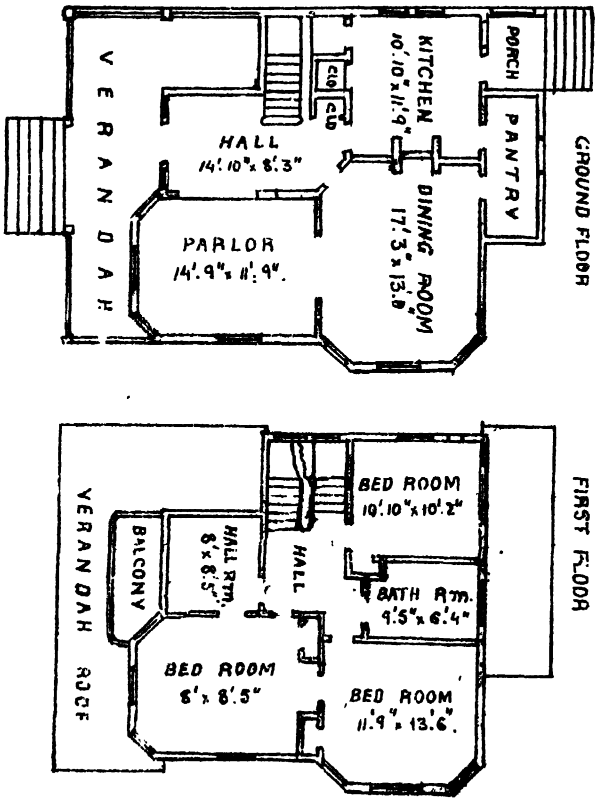
SCALE, 1-16" TO A FOOT.

GROUND FLOOR.



FIRST FLOOR



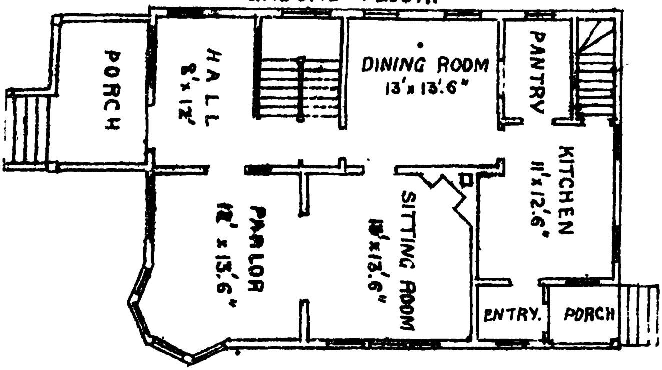


PLAN No. 67
SCALE, 1-16" TO A FOOT.

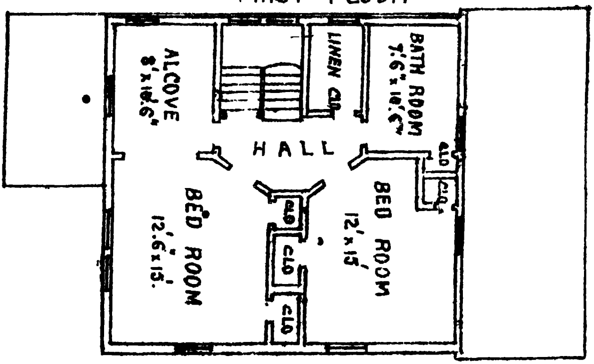
PLAN No. 68.

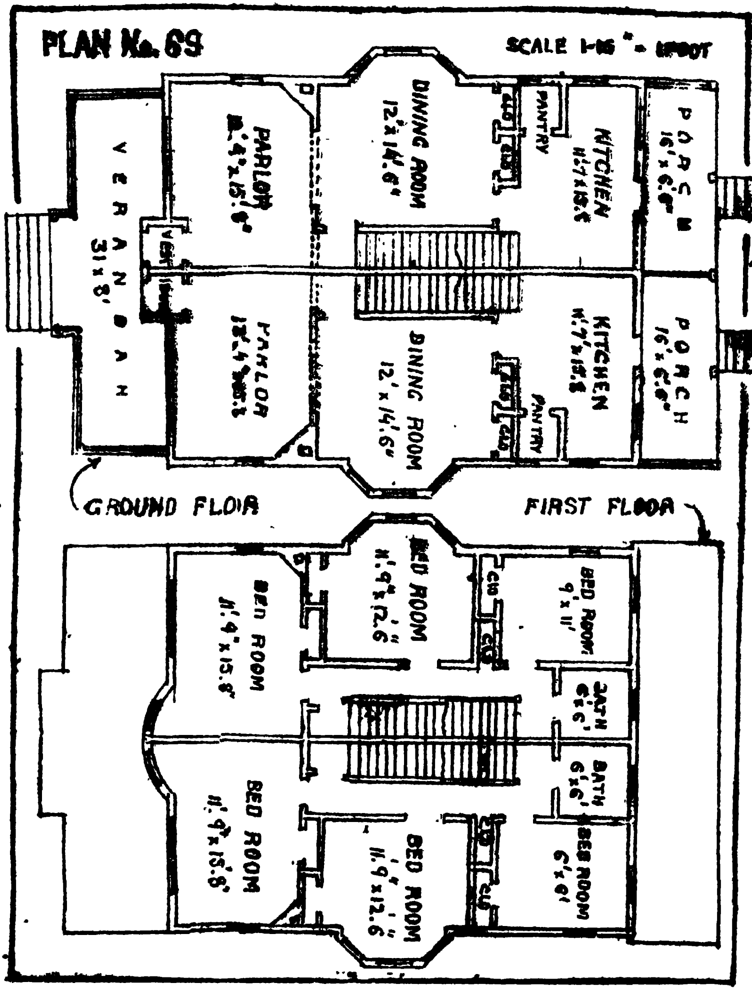
SCALE 1-16" TO A FOOT.

GROUND FLOOR.



FIRST FLOOR



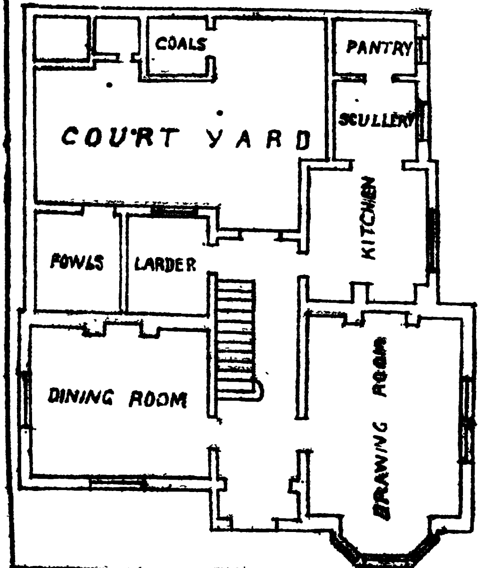


PLAN No. 69
SCALE 1-16" = 1 FOOT
VERANDAH 31 x 8'
PARLOR
DINING ROOM 12' x 14'.6"
PANTRY
KITCHEN
PORCH
DINING ROOM 12' x 14'.6"
KITCHEN
PORCH
GROUND FLOOR
FIRST FLOOR
BED ROOM 11'.4" x 15.8"
BED ROOM 11.9 x 12.6
BED ROOM 9' x 11'
BATH 6' x 6'
BATH 6' x 6'
BED ROOM 11'.9" x 15.8"
BED ROOM 11.9 x 12.6
BED ROOM 6' x 6'

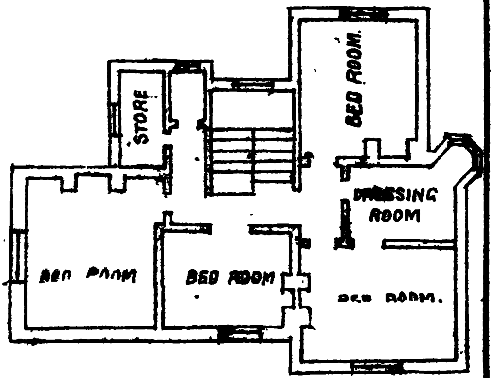
PLAN. No. 79

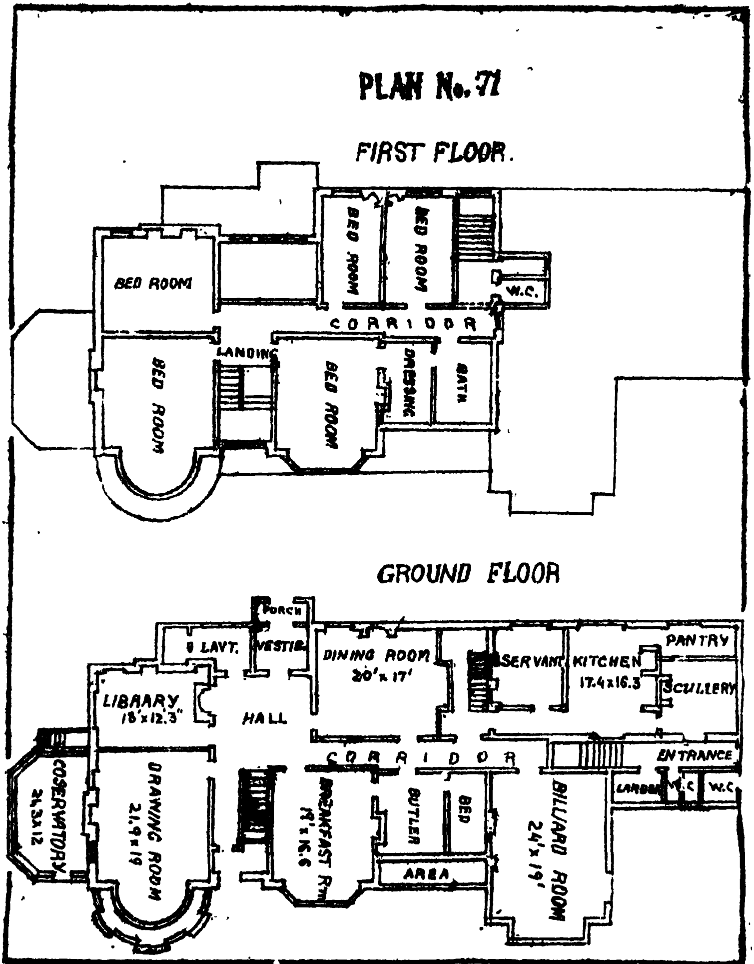
PLAN FOR A SCHOOL RESIDENCE

GROUND FLOOR



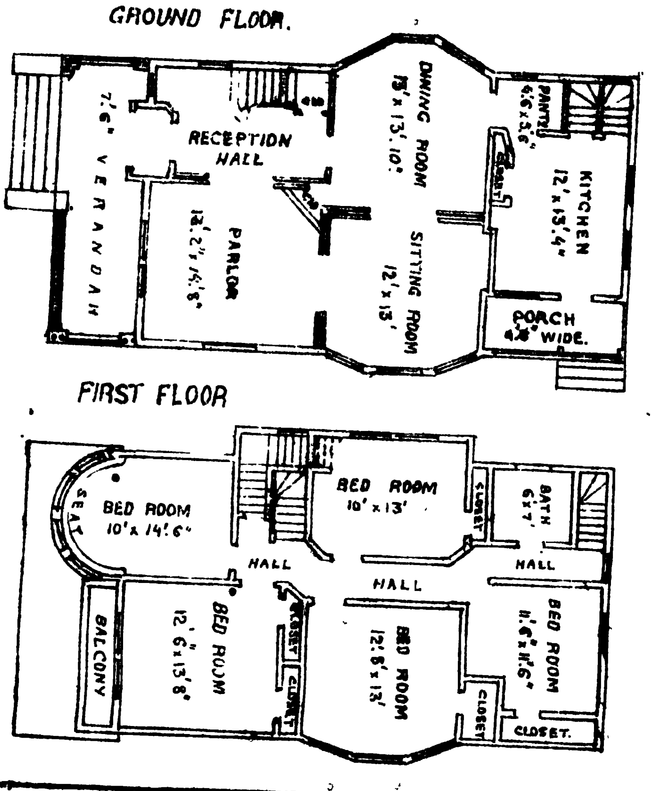
FIRST FLOOR.

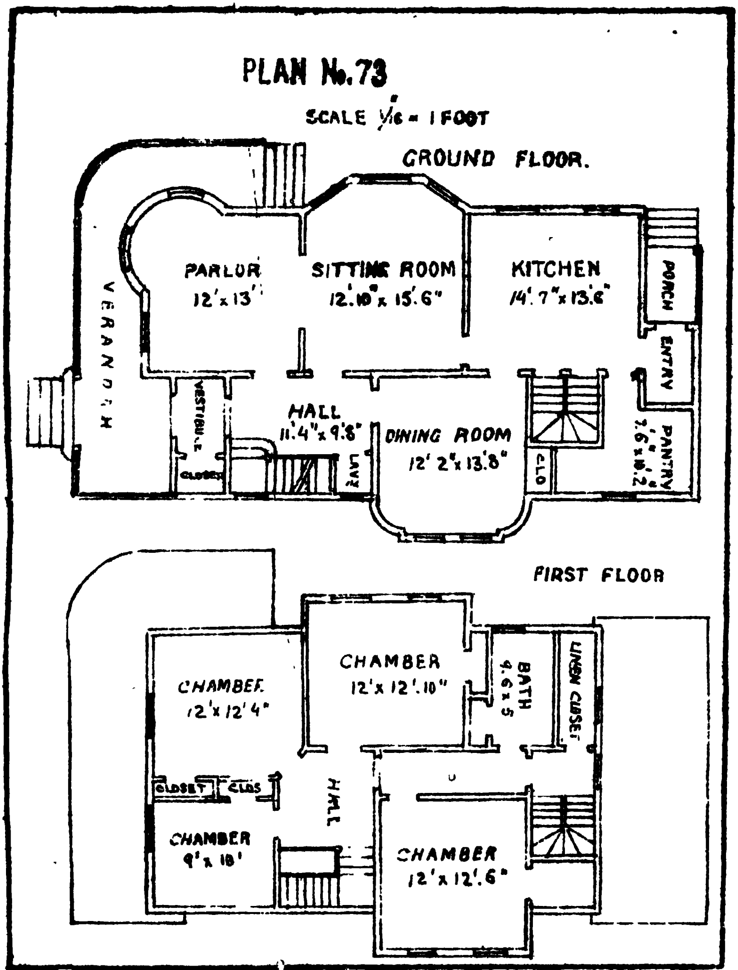



PLAN No. 71
FIRST FLOOR.
BED ROOM
BED ROOM
BED ROOM
W.C.
CORRIDOR
LANDING
BED ROOM
BED ROOM
DRESSING
BATH
GROUND FLOOR
PORCH
LAVT.
VESTIB.
DINING ROOM
20' x 17'
SERVANT
KITCHEN
17.4 x 16.3
PANTRY
SCULLERY
LIBRARY
18' x 12.3"
HALL
CORRIDOR
ENTRANCE
LARDER
W.C
W.C
COSERVATORY
21.3 x 12
DRAWING ROOM
21.9 x 19
BREAKFAST RM
17' x 16.6
BUTLER
BED
AREA
BILLIARD ROOM
24' x 19'

PLAN No. 72

SCALE 1-16" = 1 FOOT.



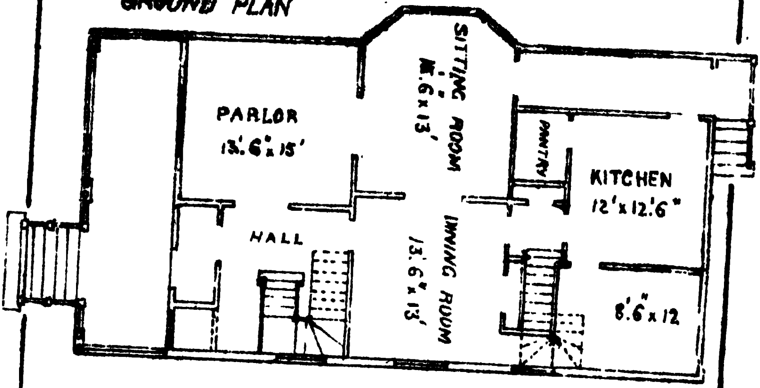


PLAN No. 73
SCALE 1/16" = 1 FOOT
GROUND FLOOR.
PARLOR
12' x 13'
SITTING ROOM
12'.10" x 15'.6"
KITCHEN
14'.7" x 13'.6"
PORCH
ENTRY
VERANDAH
VESTIBULE
CLOSET
HALL
11'.4" x 9'.8"
LAV
DINING ROOM
12' 2" x 13'.8"
CLO
PANTRY
7'.6" x 10'.2"
FIRST FLOOR
CHAMBER
12' x 12'.10"
BATH
9.6 x 5
LINEN CLOSET
CHAMBER
12' x 12' 4"
CLOSET
CLOS
HALL
CHAMBER
9' x 10'
CHAMBER
12' x 12'.6"

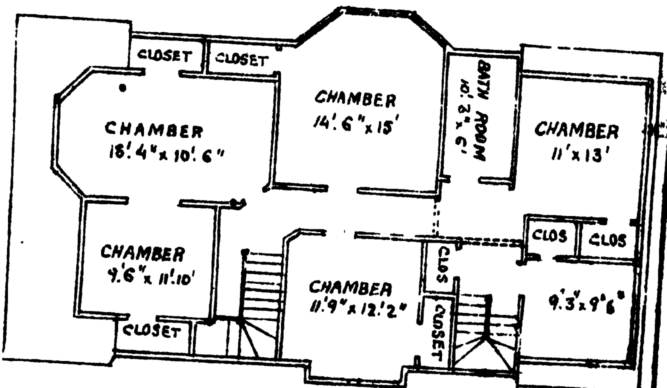
PLAN No. 74

SCALE 1/16" = 1' FOOT

GROUND PLAN

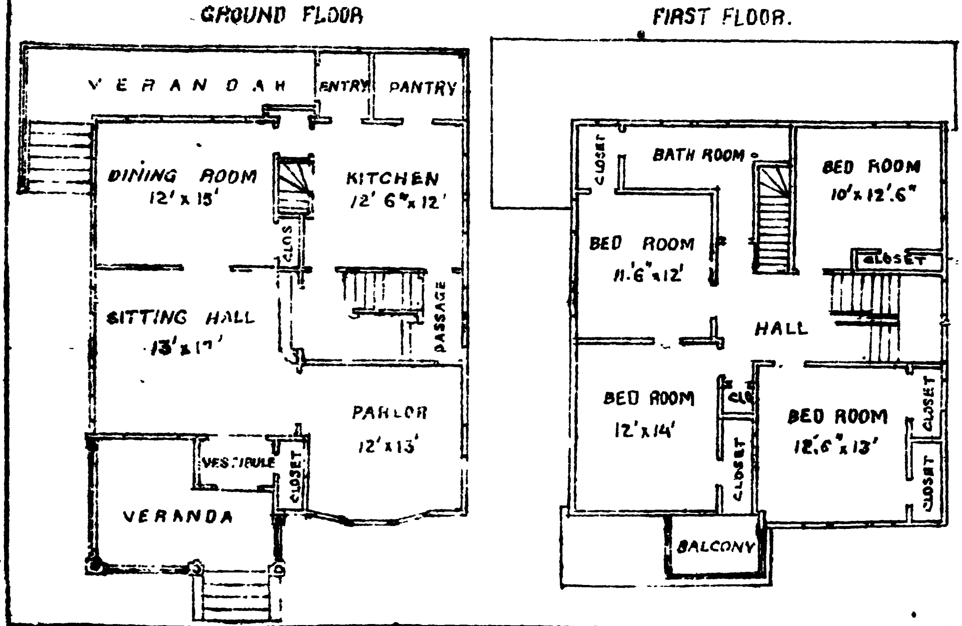


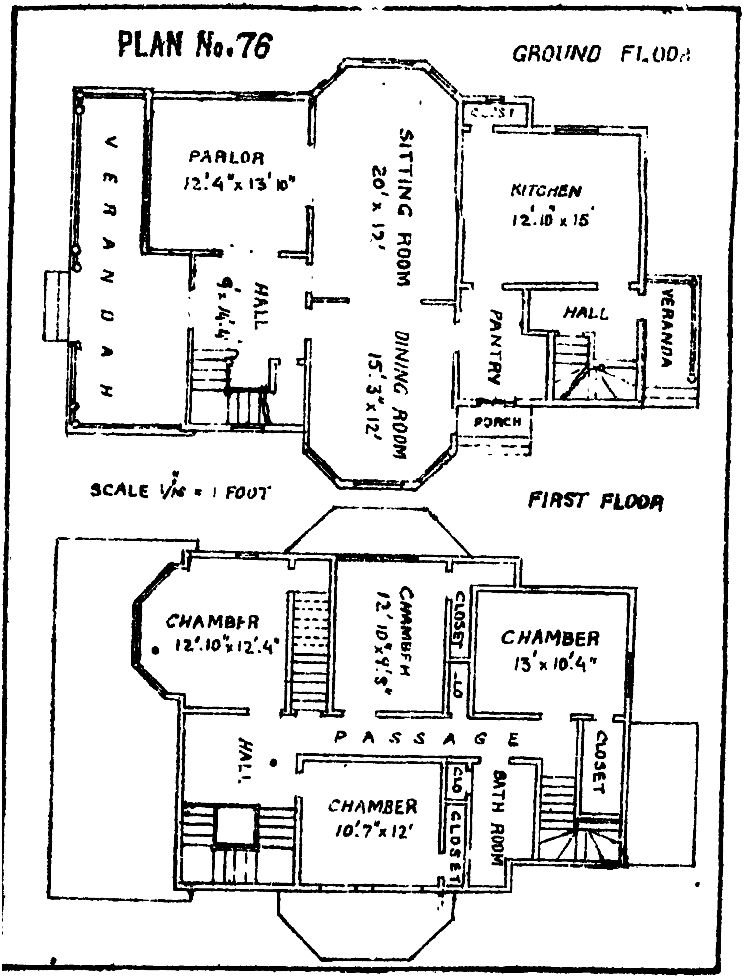
FIRST FLOOR



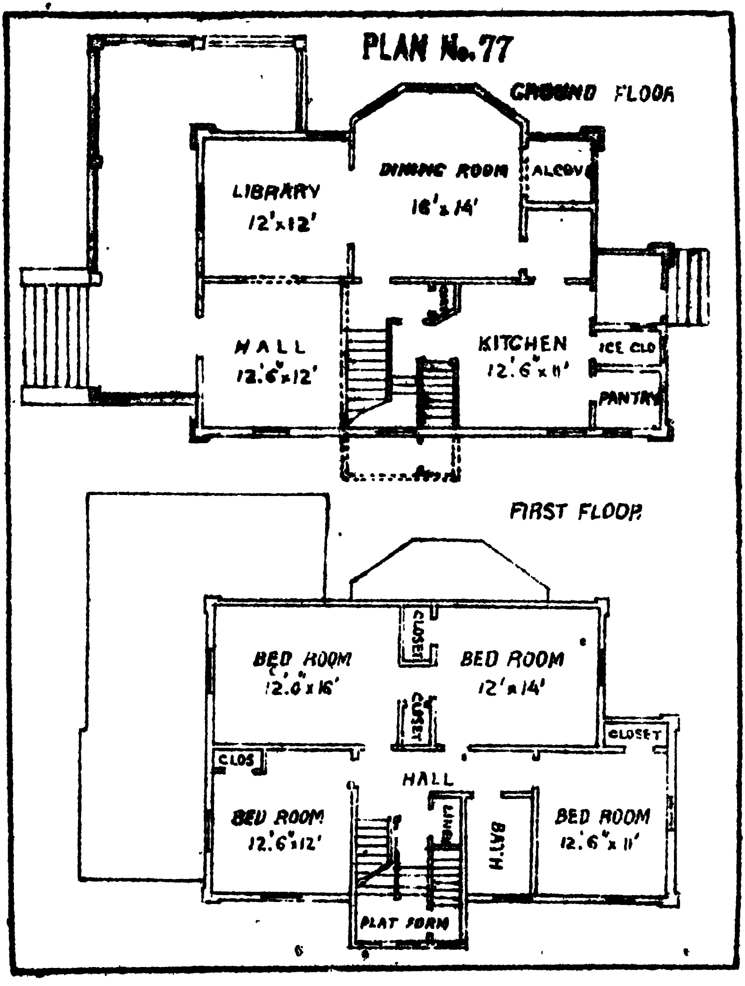
PLAN No. 75

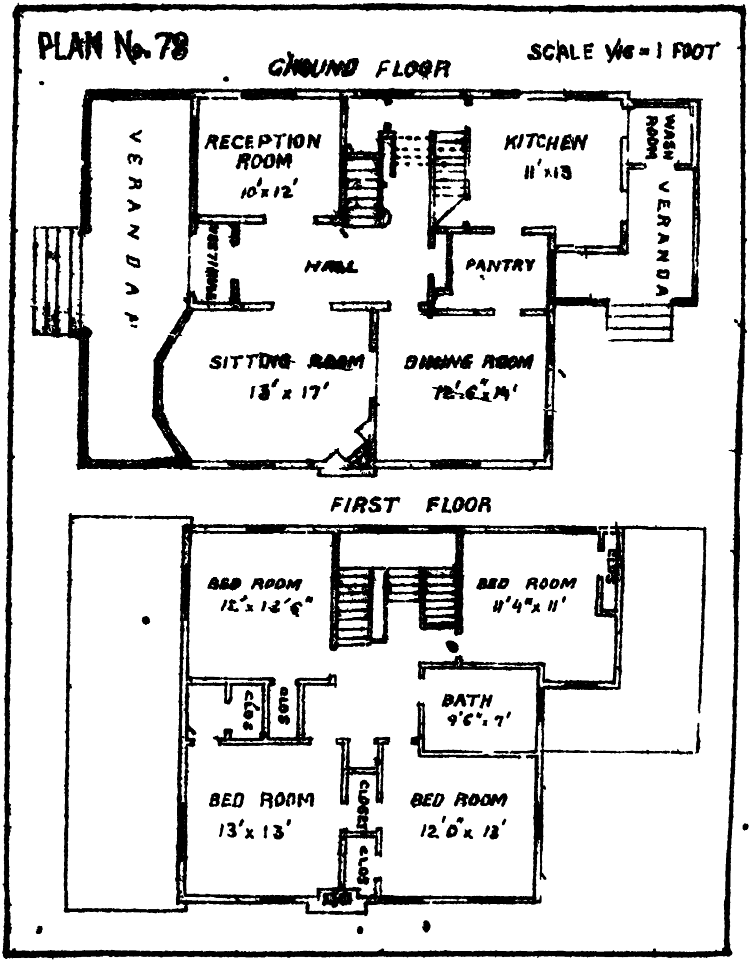
SCALE 1/16" = 1 FOOT.

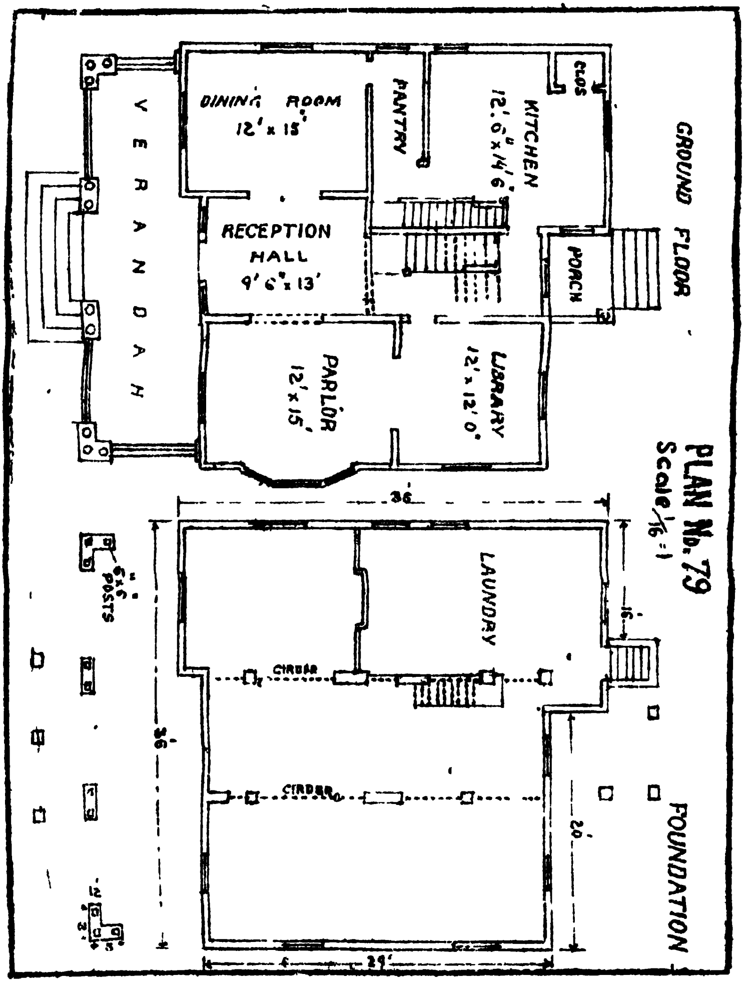



PLAN No. 76
GROUND FLOOR
VERANDAH
PARLOR
12'.4" x 13' 10"
SITTING ROOM
20' x 12'
CLOSET
KITCHEN
12'.10" x 15'
HALL
9' x 14'.4"
DINING ROOM
15'.3" x 12'
PANTRY
HALL
VERANDA
PORCH
SCALE 1/16" = 1 FOOT
FIRST FLOOR
CHAMBER
12'.10" x 12'.4"
CHAMBER
12'.10" x 9'.8"
CLOSET
CLO
CHAMBER
13' x 10'.4"
PASSAGE
HALL
CLOSET
CLO
BATH ROOM
CHAMBER
10'.7" x 12'
CLOSET

PLAN No. 77


GROUND FLOOR
LIBRARY
12'x12'
DINING ROOM
16'x14'
ALCOVE
HALL
12.'6"x12'
KITCHEN
12.'6"x11'
ICE CLO
PANTRY
FIRST FLOOR
BED ROOM
12.0"x16'
CLOSET
BED ROOM
12'x14'
CLOSET
CLOSET
CLOS
HALL
BED ROOM
12.'6"x12'
LINEN
BATH
BED ROOM
12.'6"x11'
PLAT FORM

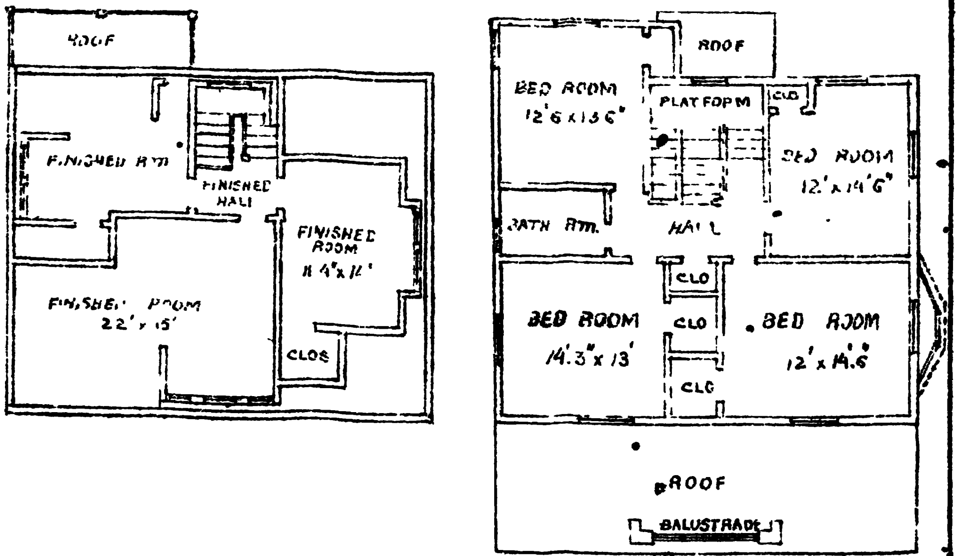

PLAN No. 78
SCALE 1/16 = 1 FOOT
GROUND FLOOR
VERANDA
RECEPTION ROOM
10' x 12'
KITCHEN
11' x 13
WASH ROOM
VERANDA
HALL
PANTRY
SITTING ROOM
13' x 17'
DINING ROOM
FIRST FLOOR
BED ROOM
12' x 12' 6"
BED ROOM
11' 4" x 11'
BATH
9' 6" x 7'
BED ROOM
13' x 13'
CLOSET
BED ROOM
12' 0" x 13'

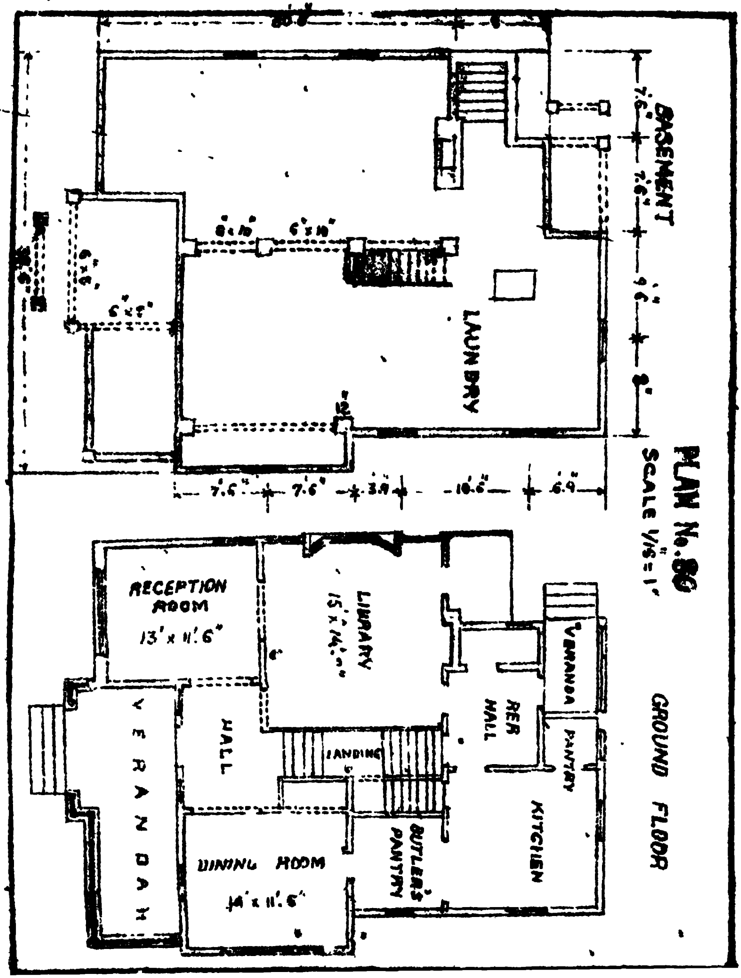


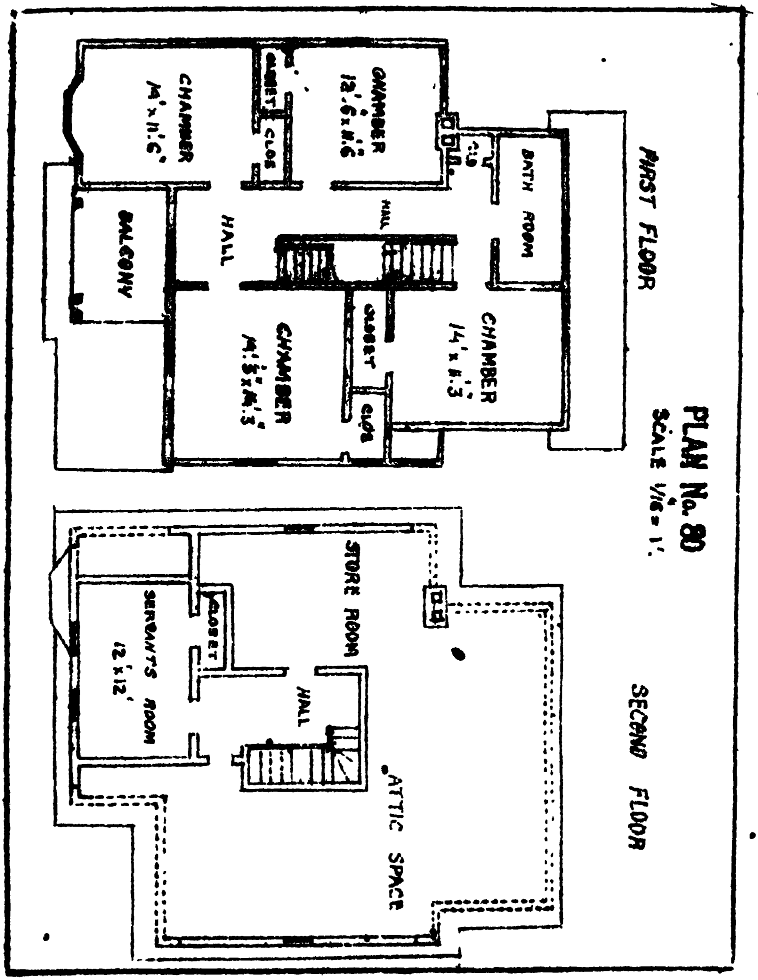
PLAN No. 79
Scale 1/16 : 1
GROUND FLOOR
DINING ROOM
12' x 15'
PANTRY
KITCHEN
12'6" x 14'6"
CLOS
VERANDAH
RECEPTION
HALL
9'6" x 13'
PORCH
PARLOR
12' x 15'
LIBRARY
12' x 12'0"
FOUNDATION
LAUNDRY
GIRDER
GIRDER
6"x6" POSTS
36'
36'
29'
20'
16'

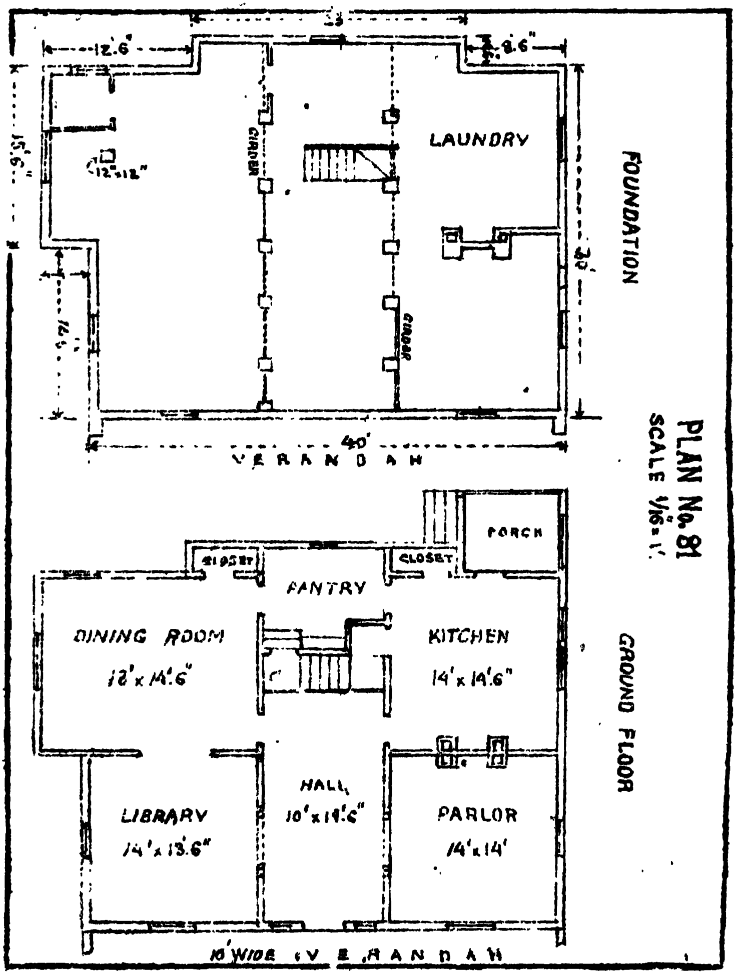
PLAN No. 79

SECOND FLOOR — SCALE 1/16" = 1 FOOT — FIRST FLOOR

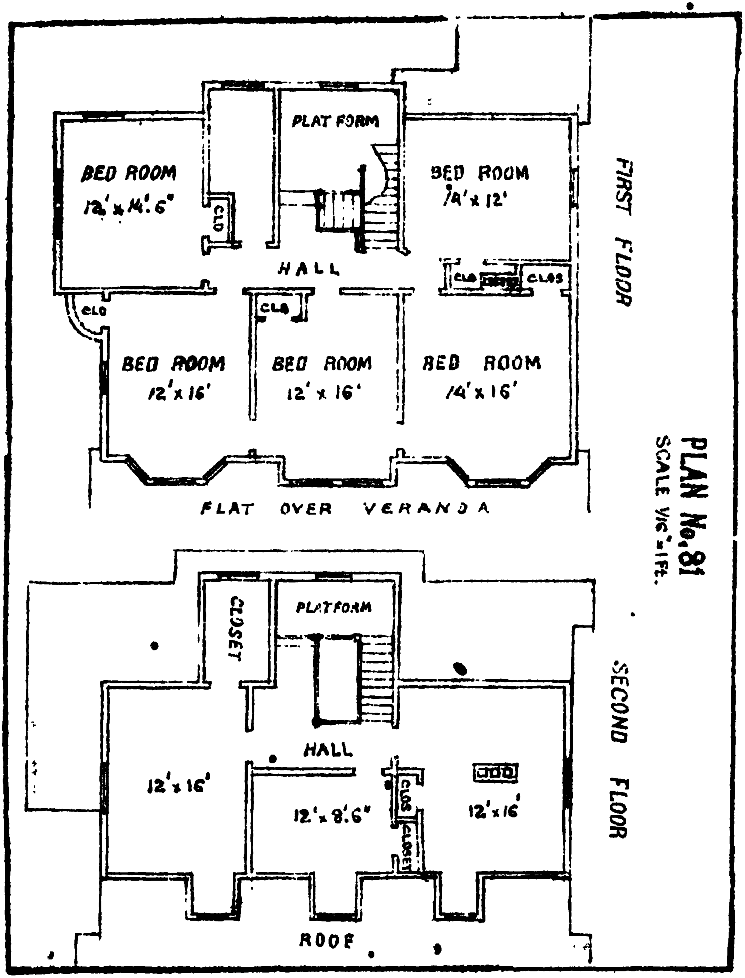


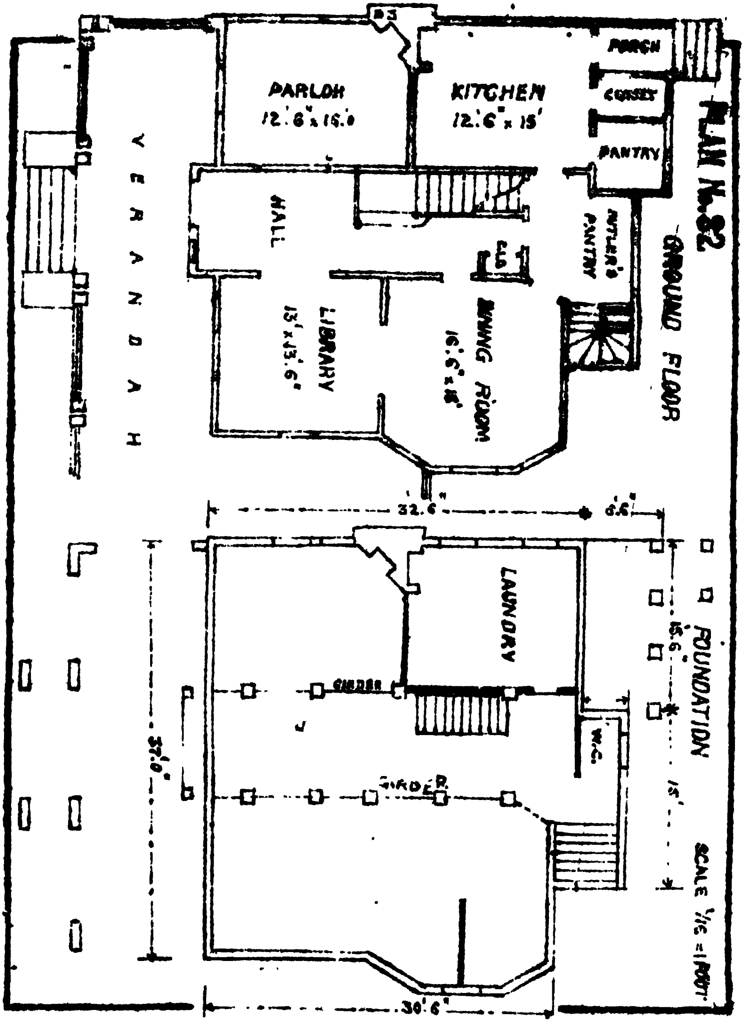

PLAN No. 86
SCALE 1/16" = 1'
BASEMENT
LAUNDRY
GROUND FLOOR
RECEPTION ROOM
13' x 11'.6"
LIBRARY
HALL
VERANDAH
LANDING
DINING ROOM
14' x 11'.6"
BUTLER'S PANTRY
KITCHEN
PANTRY
REAR HALL
VERANDA


PLAN No. 80
SCALE 1/16 = 1'
FIRST FLOOR
CHAMBER
14' x 11.6"
CHAMBER
12.6 x 11.6
CLOSET
CLOS
BATH ROOM
HALL
HALL
BALCONY
CHAMBER
14'.3 x 14'.3
CLOSET
CLOS
CHAMBER
14' x 11.3
SECOND FLOOR
STORE ROOM
SERVANTS ROOM
12 x 12'
CLOSET
HALL
ATTIC SPACE

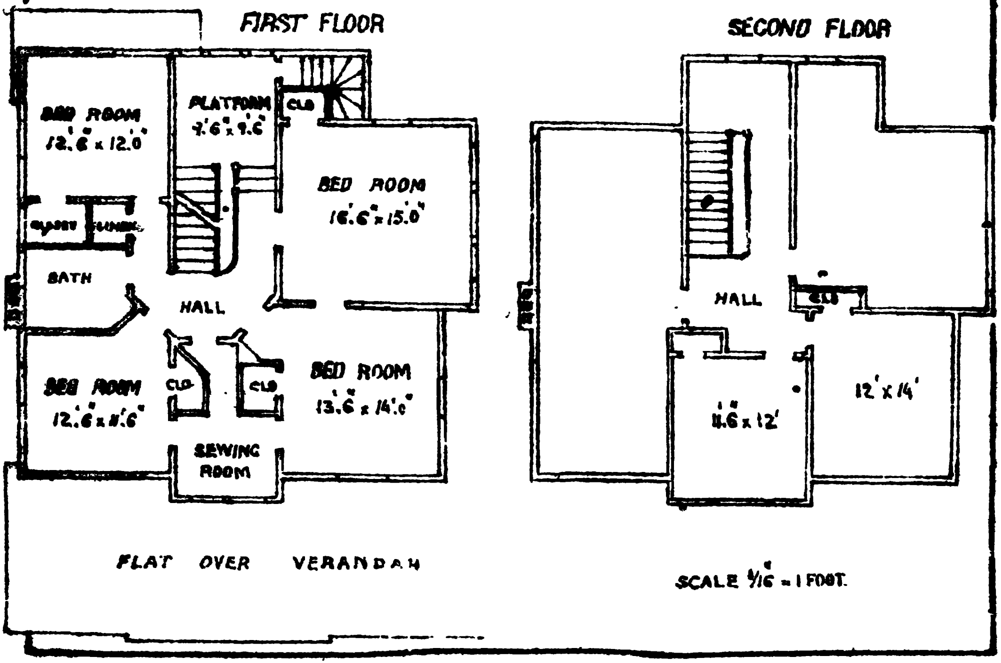


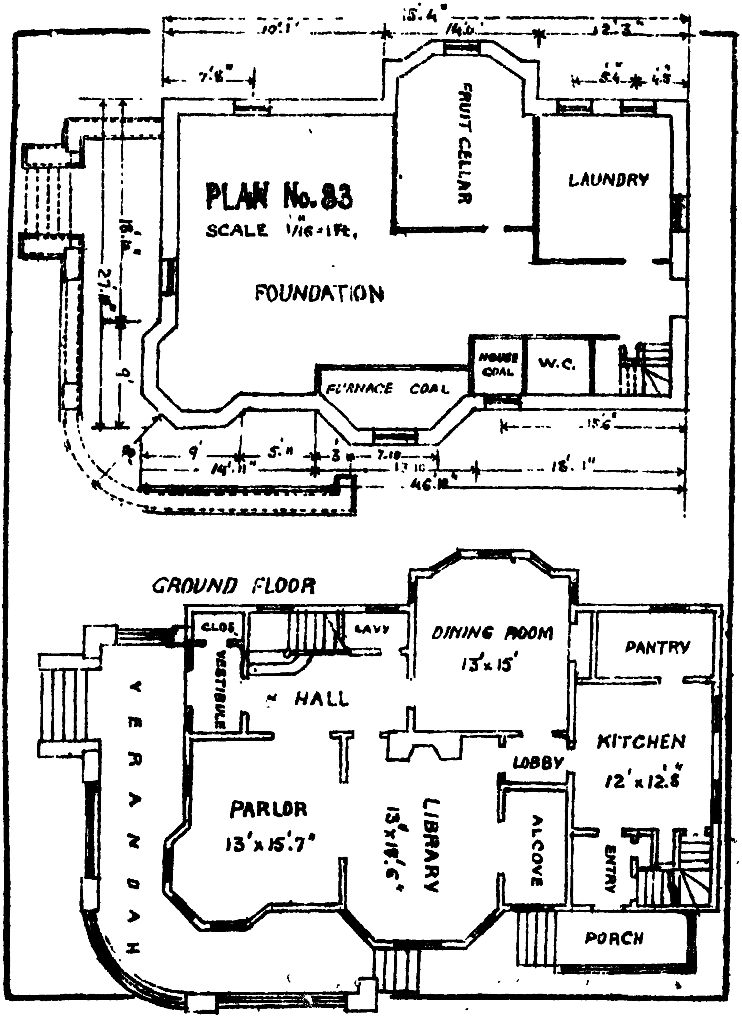
PLAN No. 81
SCALE 1/16" = 1'.

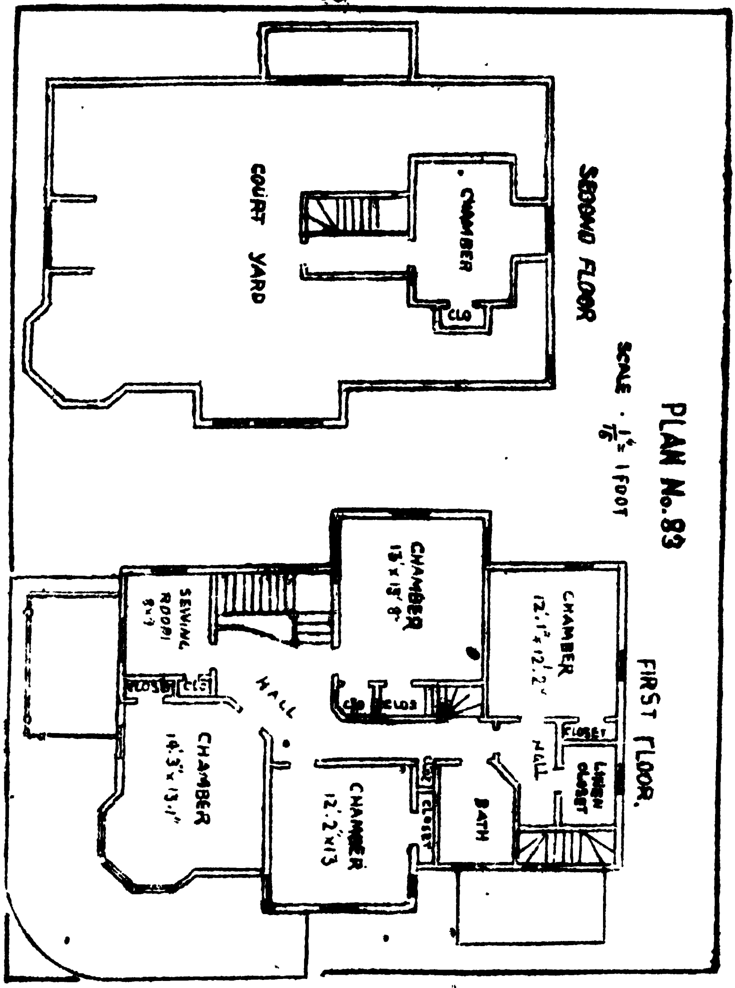

PLATFORM
BED ROOM
12' x 14'.6"
CLO
BED ROOM
14' x 12'
HALL
CLO
CLOS
CLO
CLO
BED ROOM
12' x 16'
BED ROOM
12' x 16'
BED ROOM
14' x 16'
FLAT OVER VERANDA
FIRST FLOOR
PLAN No. 81
SCALE 1/16" = 1 FT.
PLATFORM
CLOSET
HALL
12' x 16'
12' x 8'.6"
CLOS
CLOSET
12' x 16'
ROOF
SECOND FLOOR


PARLOR
KITCHEN
PORCH
CLOSET
PANTRY
HALL
LIBRARY
VERANDAH
PLAN No. 82
GROUND FLOOR
LAUNDRY
FOUNDATION
GIRDER
W.C.
30'6"

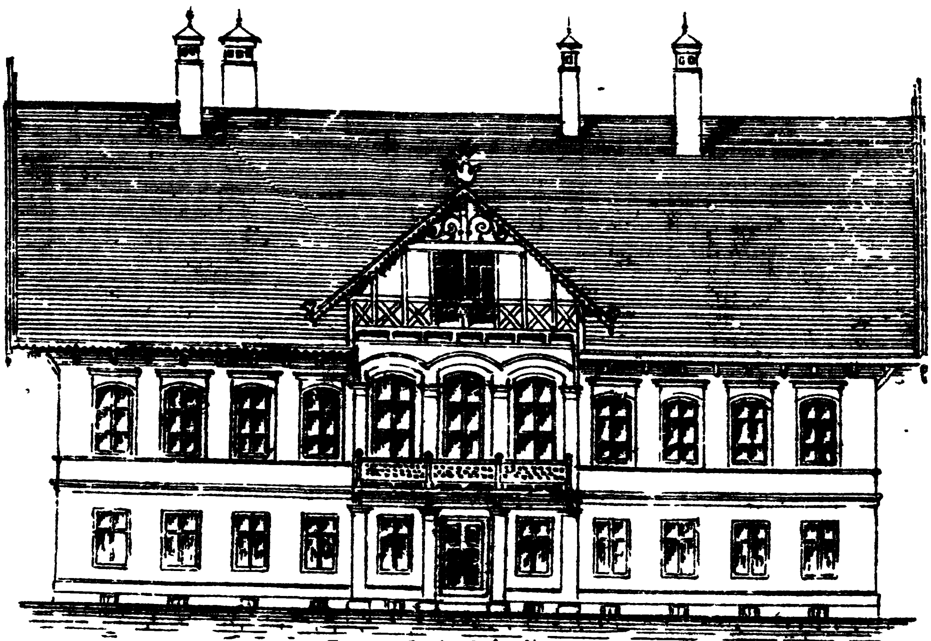
PLAN No. 82


FIRST FLOOR
SECOND FLOOR
BED ROOM
12.6 x 12.0
PLATFORM
7.6 x 9.6
CLO
BED ROOM
16.6 x 15.0
CLOSET
LINEN
BATH
HALL
BED ROOM
12.6 x 11.6
CLO
CLO
BED ROOM
13.6 x 14.0
SEWING ROOM
FLAT OVER VERANDAH
HALL
CLO
12 x 14
11.6 x 12
SCALE 1/16" = 1 FOOT.


PLAN No. 83
SCALE 1/16"=1 Ft.
FOUNDATION
FRUIT CELLAR
LAUNDRY
HOUSE COAL
W.C.
FURNACE COAL
GROUND FLOOR
CLOS
LAVY
VESTIBULE
HALL
DINING ROOM
13' x 15'
PANTRY
KITCHEN
12' x 12.8"
LOBBY
VERANDAH
PARLOR
13' x 15'.7"
LIBRARY
ALCOVE
ENTRY
PORCH


PLAN No. 83
SCALE · 1/16" = 1 FOOT
SECOND FLOOR
CHAMBER
CLO
COURT YARD
FIRST FLOOR.
CHAMBER
12'.1" x 12'.2"
CLOSET
LINEN CLOSET
HALL
BATH
CHAMBER
13' x 13' 8"
CLOS
CLO
CLO
CLOSET
CHAMBER
12'.2" x 13
HALL
CHAMBER
14'.3" x 13.1"
SEWING ROOM
8 x 9
CLOSET

PLAN NO. 84 ELEVATION OF A DWELLING HOUSE



Scale 20' = 1"

PLAN No. 85

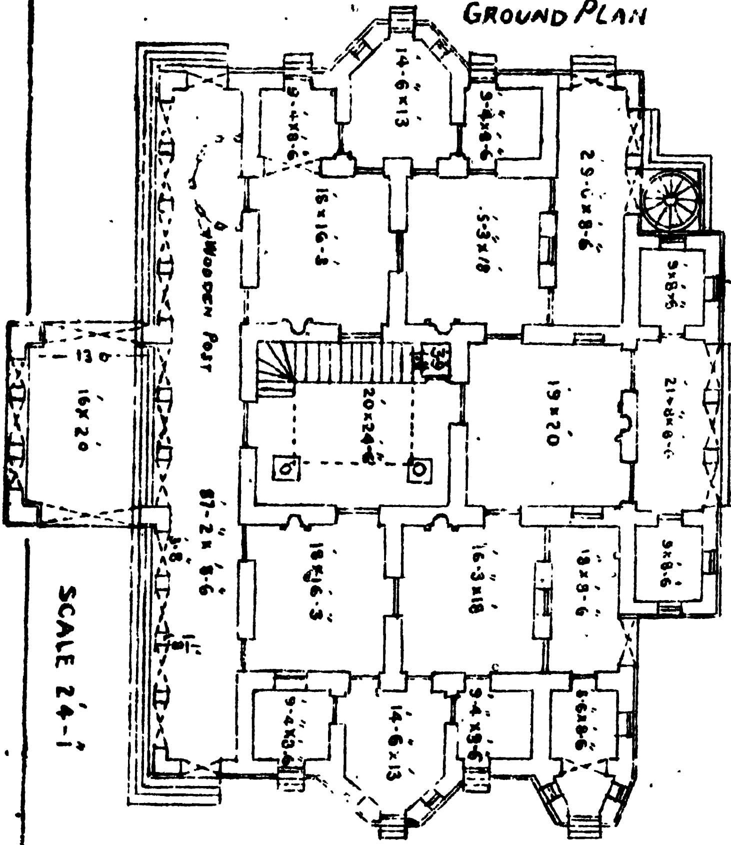
ELEVATION OF A DWELLING HOUSE



Scale 20′=1″

PLAN No. 86

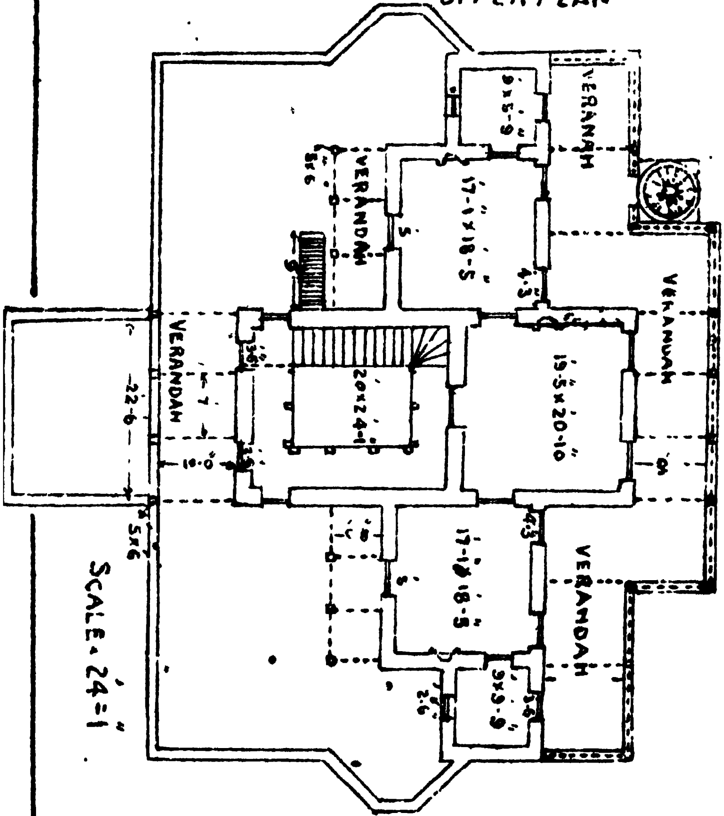
GROUND PLAN



SCALE 24-1

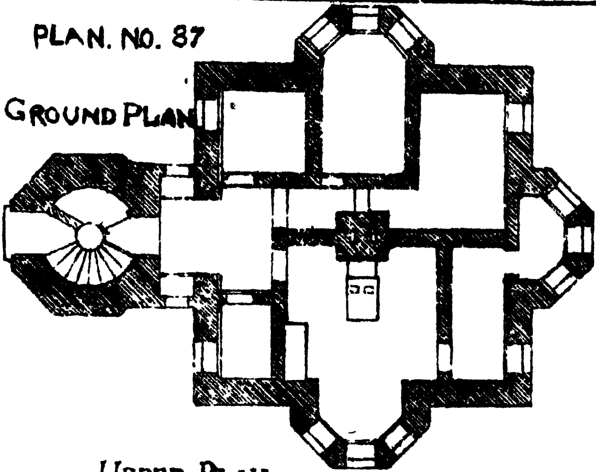
PLAN. No. 86

UPPER PLAN



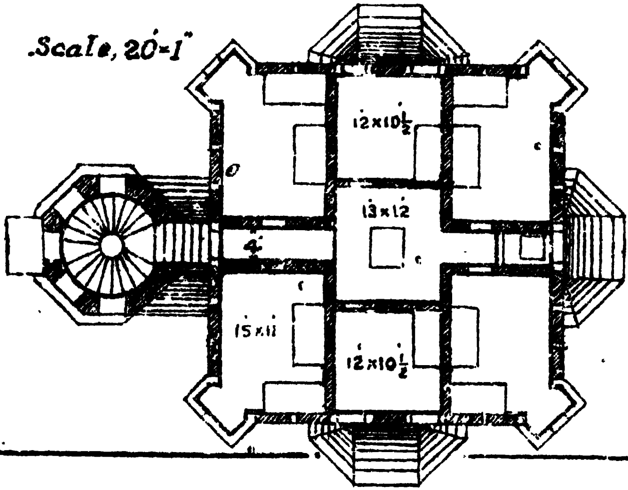
PLAN. NO. 87

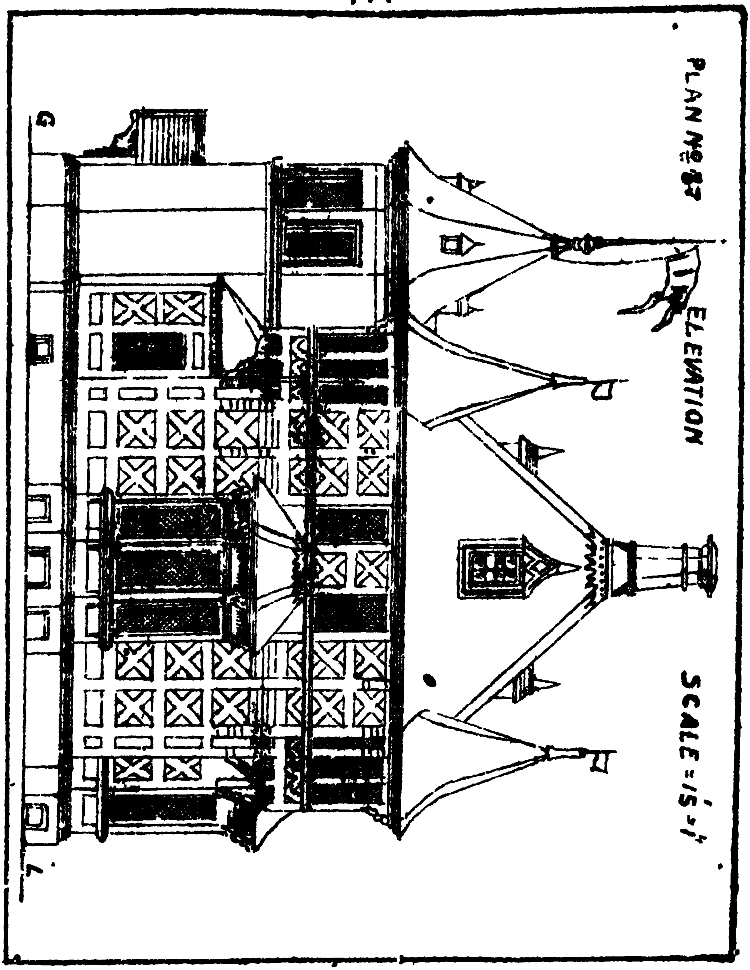
GROUND PLAN



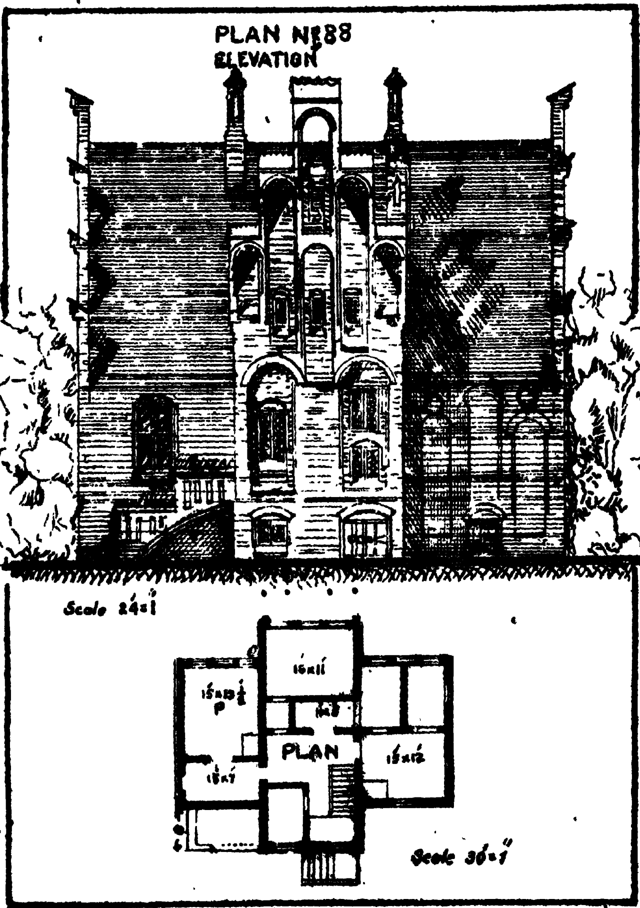
UPPER PLAN

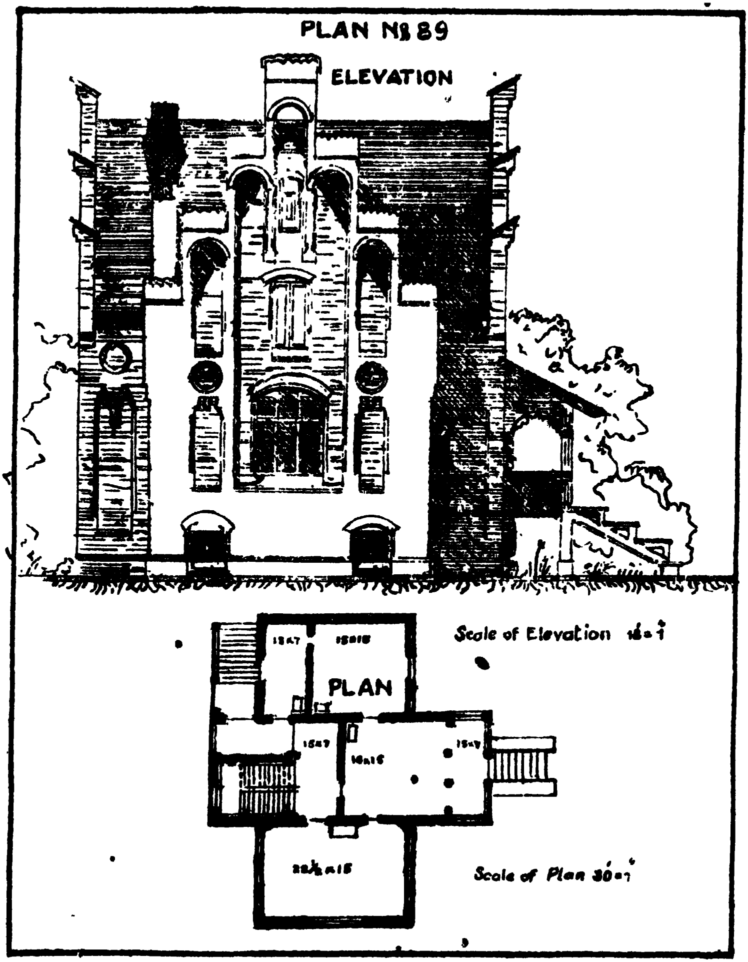
Scale, 20'=1"

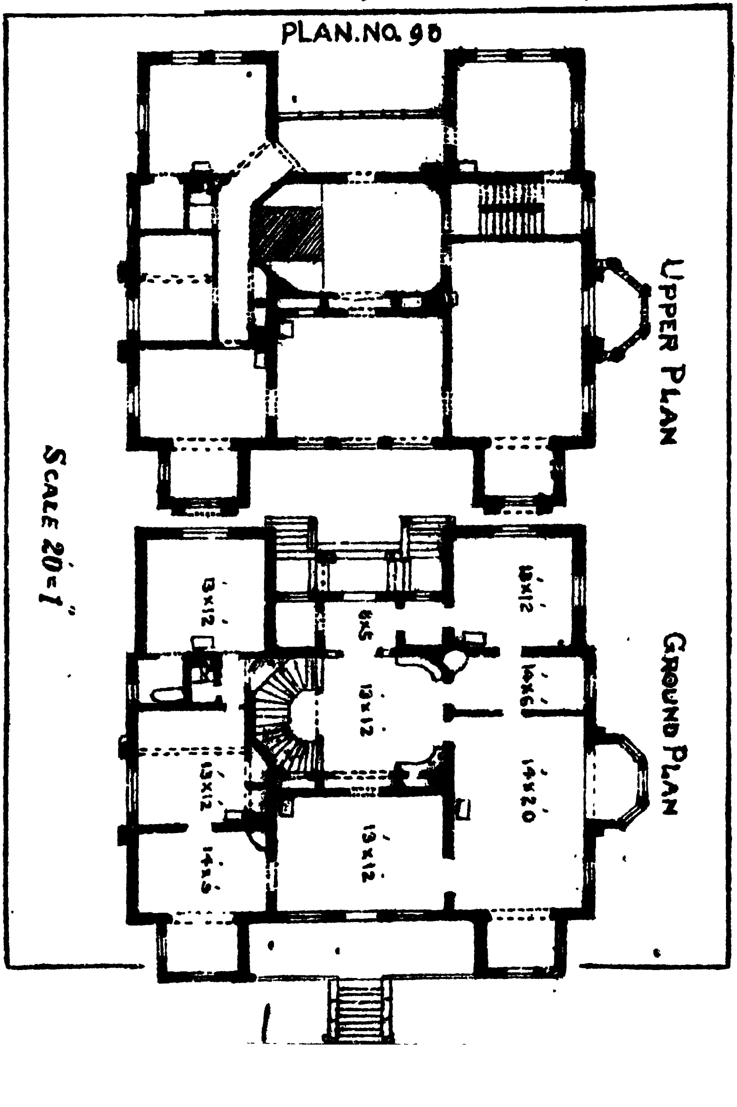




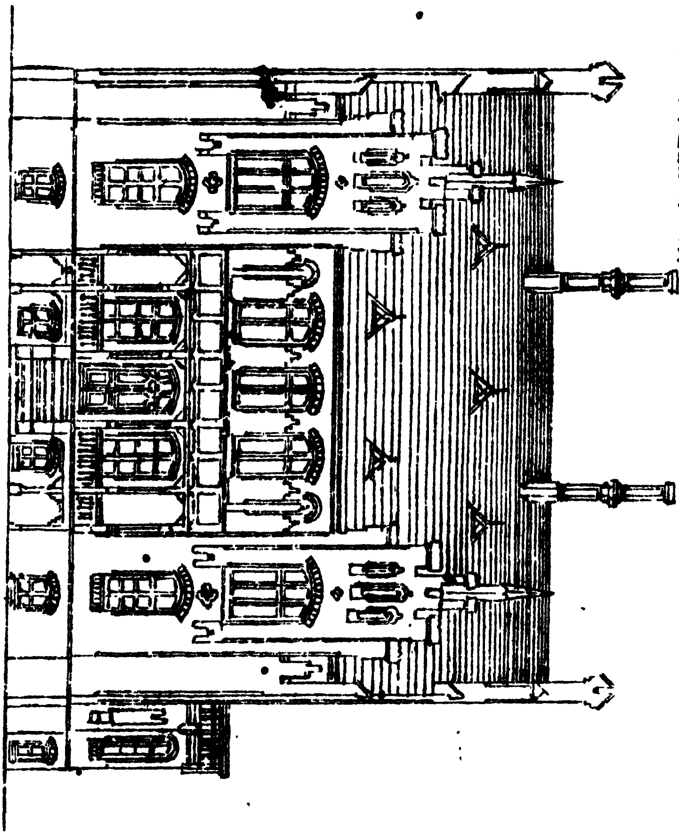
PLAN No. 87
ELEVATION
SCALE = 15'-1"
G
L


PLAN No 88
ELEVATION
Scale 24'=1"
15x11
PLAN
15x12
Scale 30'=1"


PLAN No 89
ELEVATION
Scale of Elevation 16'=1"
PLAN
Scale of Plan 30'=1"


PLAN. NO. 90
UPPER PLAN
GROUND PLAN
SCALE 20'=1"

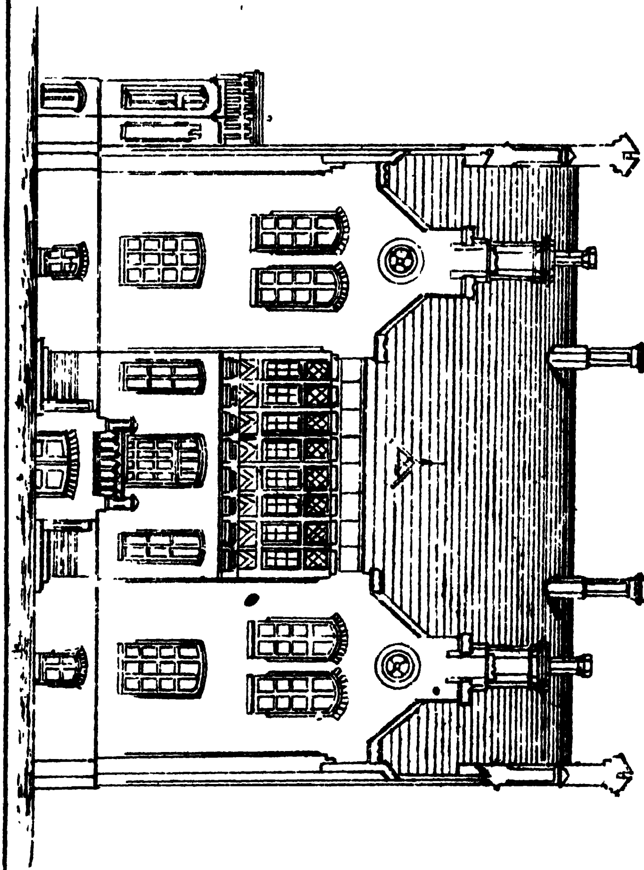
PLAN NO. 90



FRONT ELEVATION

SCALE 15'=1"

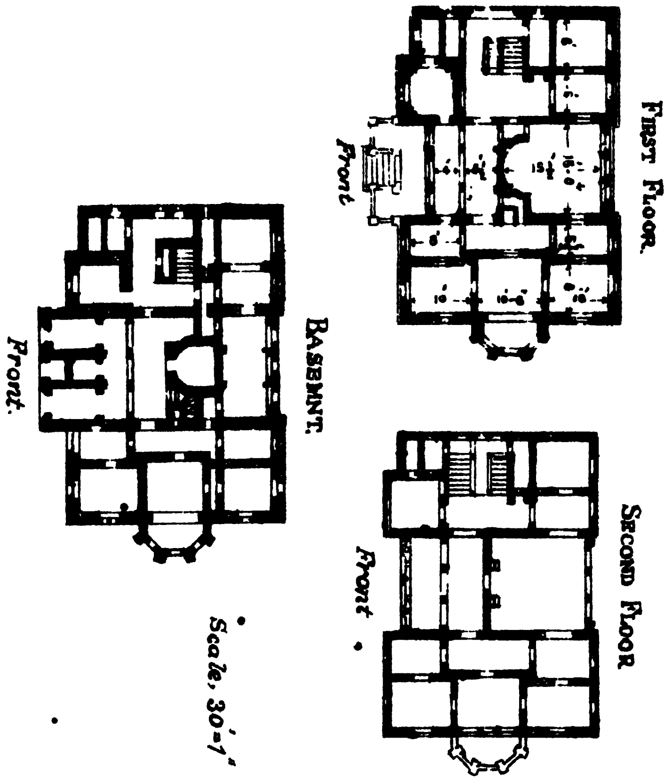
PLAN. No. 90



BACK ELEVATION

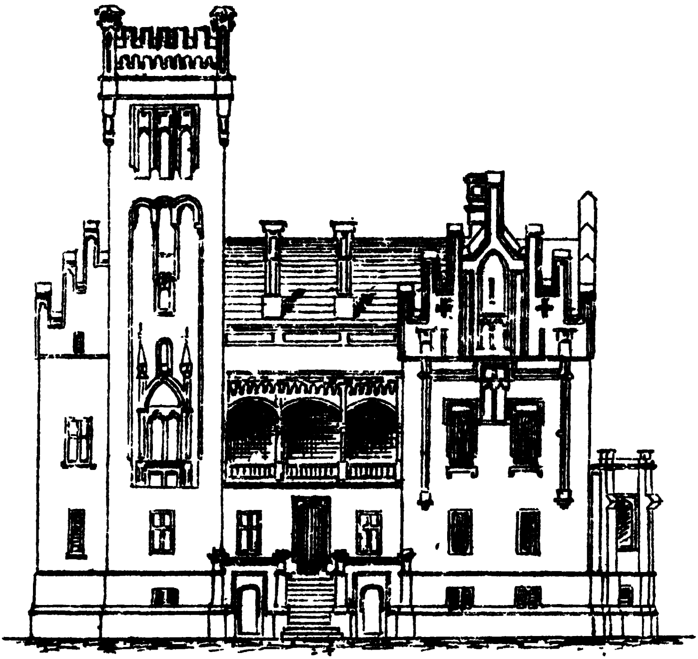
Scale, 15'-1"

PLAN NO. 41


FIRST FLOOR
Front
BASEMNT.
Front.
SECOND FLOOR
Front
Scale, 30'=1"

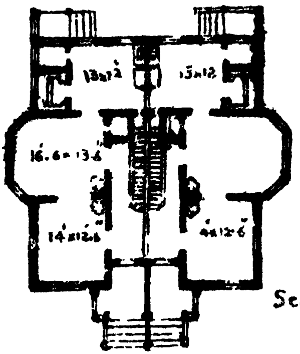
PLAN NO. 91

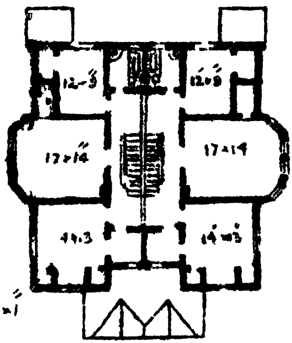
FRONT ELEVATION.



Scale, 16' = 1"

PLAN. NO 92





Scale, 30' = 1"

FIRST FLOOR

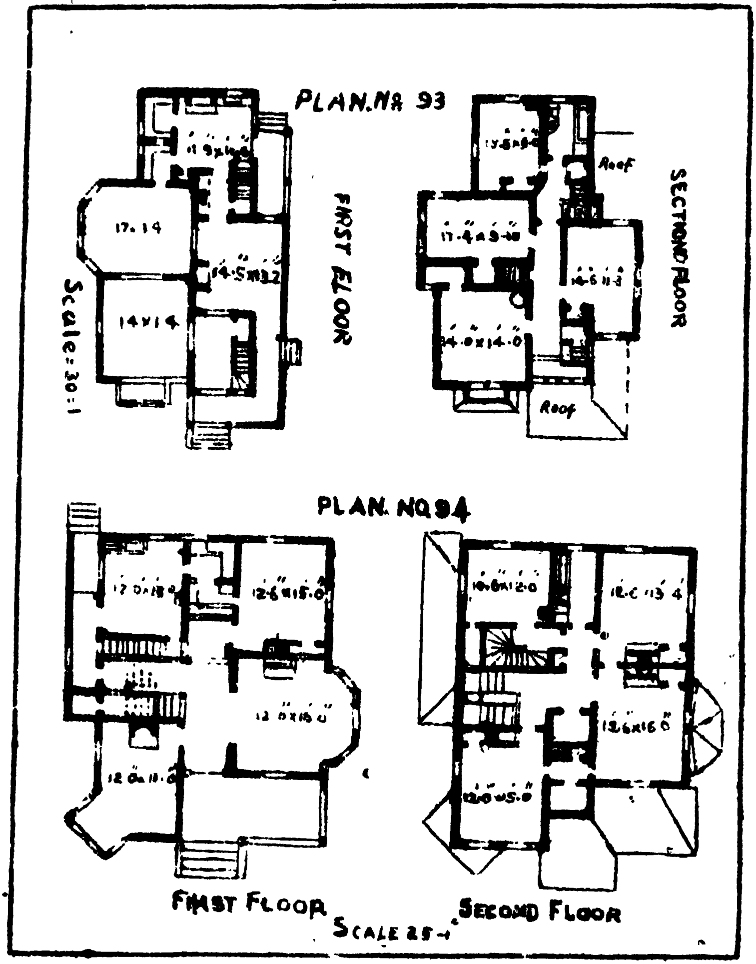
SECOND FLOOR

FRONT ELEVATION

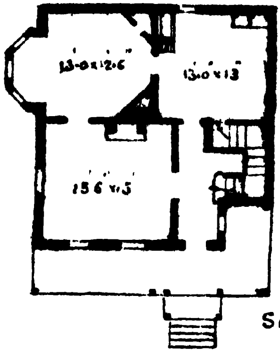
SIDE ELEVATION

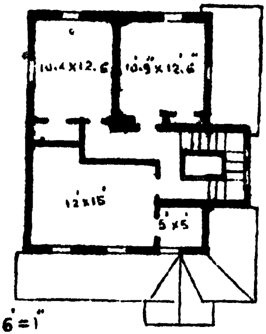





PLAN. No. 93
FIRST FLOOR
Scale = 30 : 1
SECOND FLOOR
Roof
Roof
17 x 14
14 x 14
14.0 x 14.0
PLAN. No. 94
FIRST FLOOR
SECOND FLOOR
SCALE 25 - 1

PLAN. NO 95

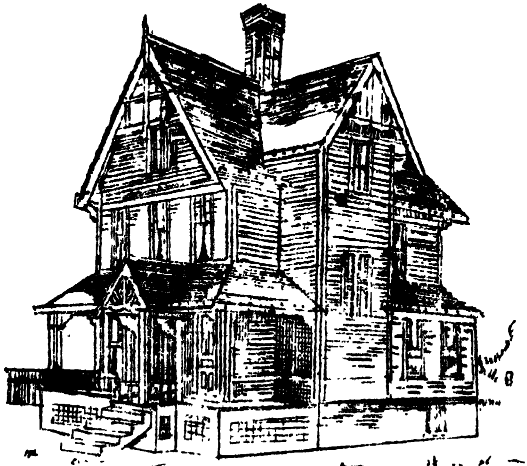




Scale, 16'=1"

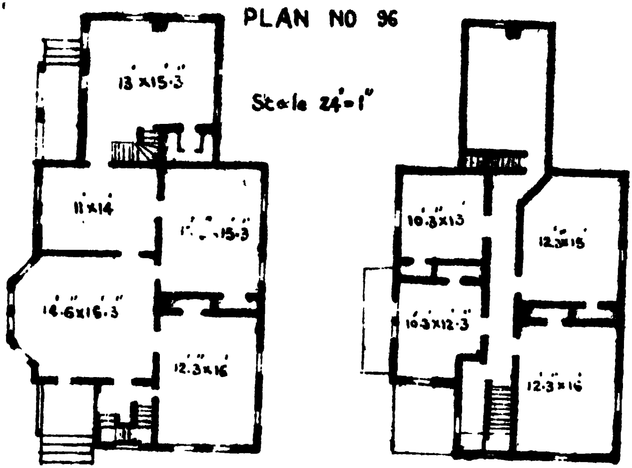
FIRST FLOOR. SECOND FLOOR.

PERSPECTIVE VIEW.



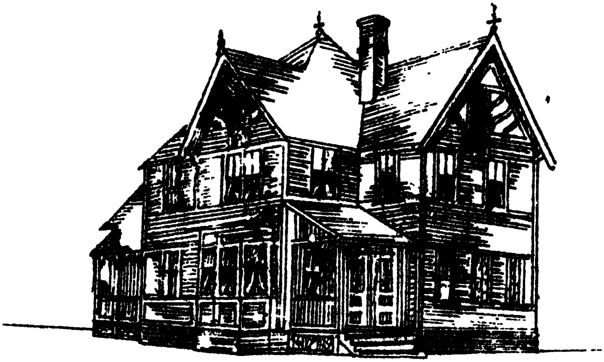
PLAN NO 96

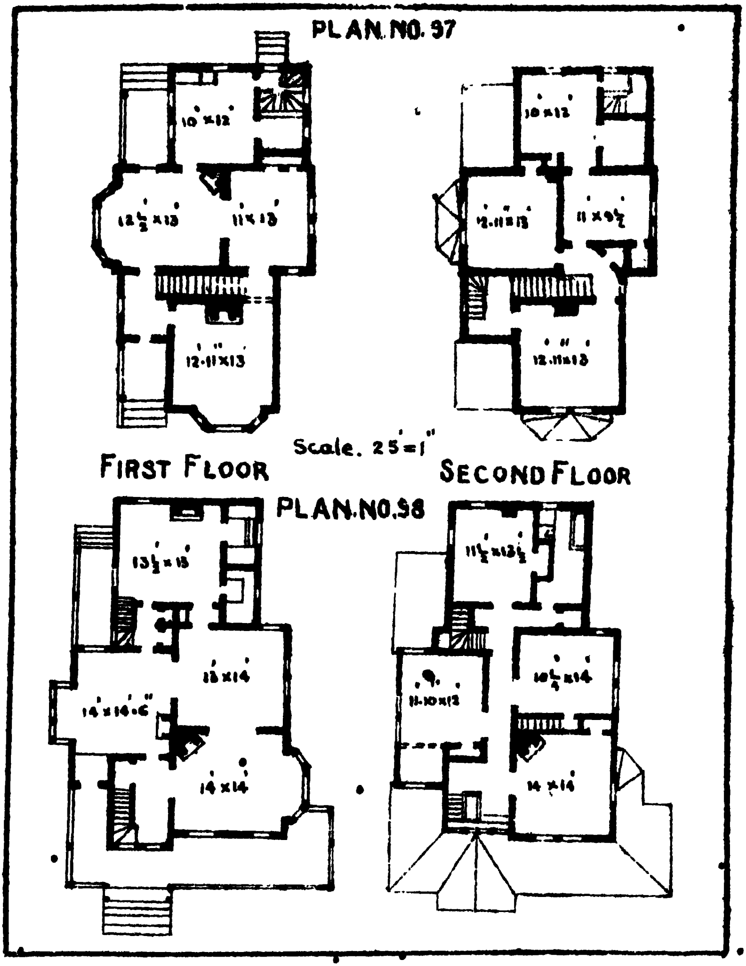
Scale 24'=1"

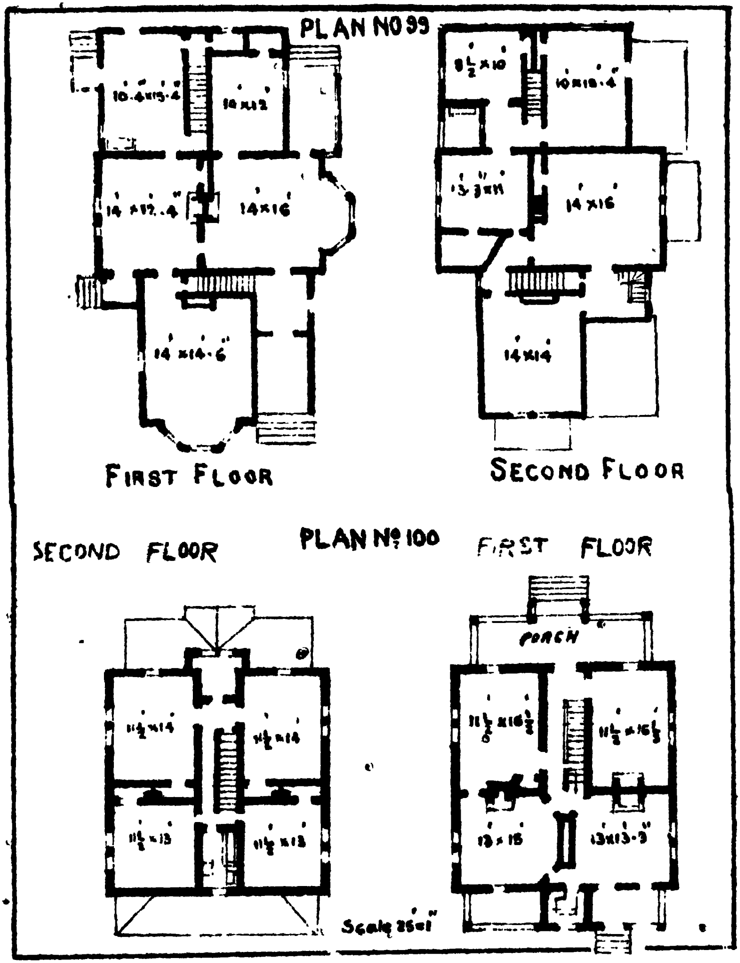


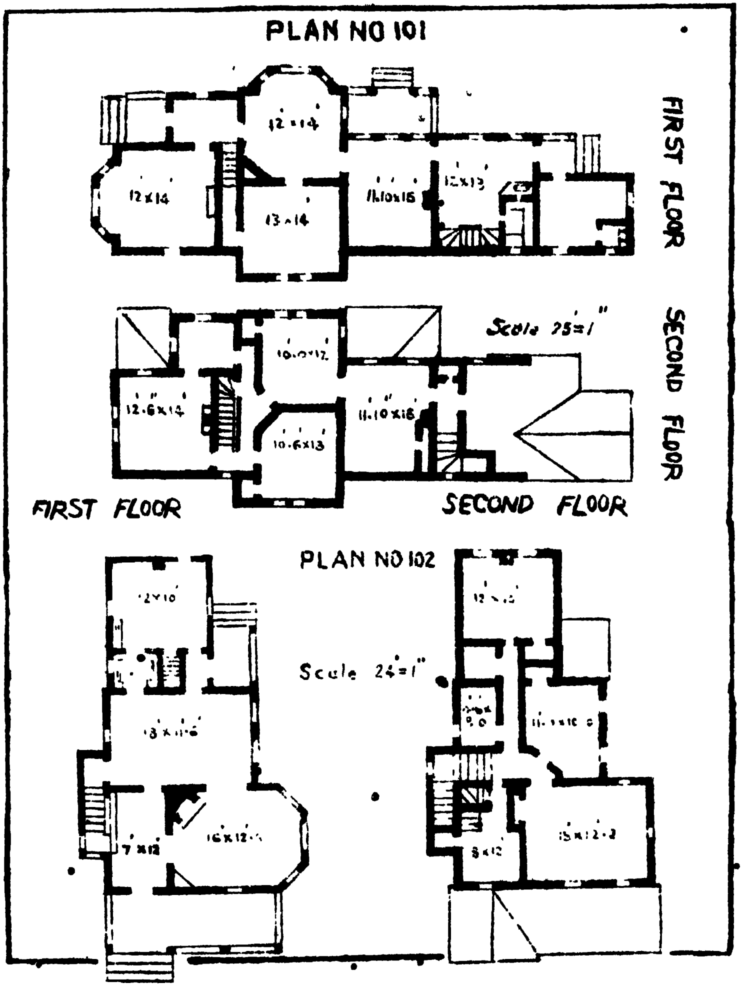
FIRST FLOOR SECOND FLOOR

PERSPECTIVE VIEW

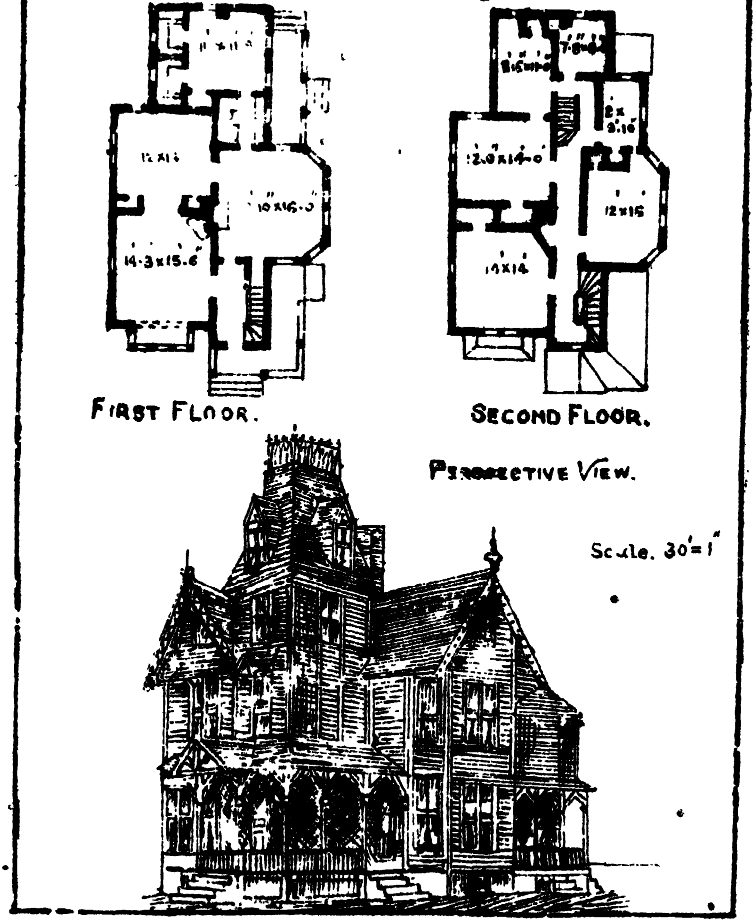


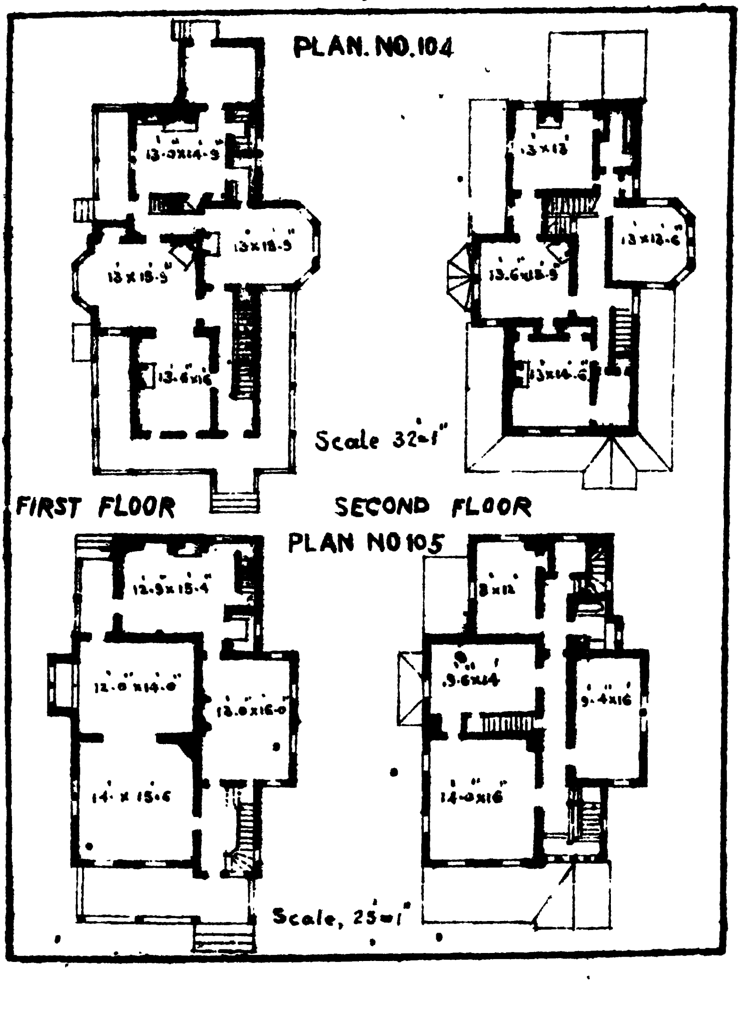

PLAN. NO. 97
Scale. 25'=1"
FIRST FLOOR
SECOND FLOOR
PLAN. NO. 98


PLAN NO 99
10.4×15.4
14×12
14×17.4
14×16
14×14.6
FIRST FLOOR
9½×10
10×15.4
13.3×11
14×16
14×14
SECOND FLOOR
SECOND FLOOR
PLAN No. 100
FIRST FLOOR
11½×14
11½×14
11½×13
11½×13
PORCH
11½×16½
11½×16½
13×15
13×13.3
Scale 25=1

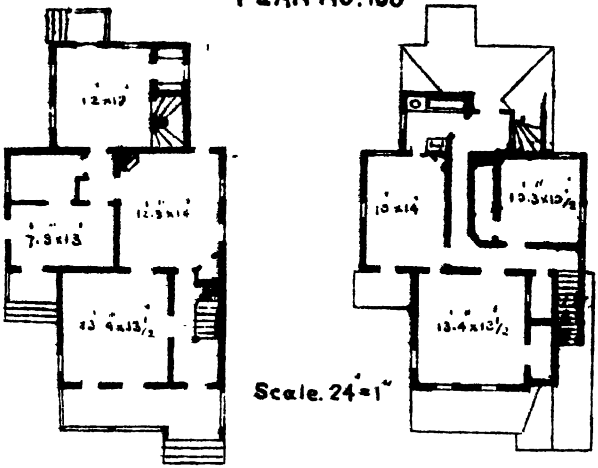

PLAN NO 101
12×14
12×14
13×14
11.10×16
12×13
FIRST FLOOR
Scale 25=1"
10.0×12
12.6×14
10.6×13
11.10×16
SECOND FLOOR
FIRST FLOOR
SECOND FLOOR
PLAN NO 102
Scale 24=1"
12×10
13×11.6
7×12
16×12
15×12.2
8×12

PLAN NO. 103


12.0x14-0
12x15
14x14
14-3x15-6
FIRST FLOOR.
SECOND FLOOR.
PERSPECTIVE VIEW.
Scale. 30' = 1"

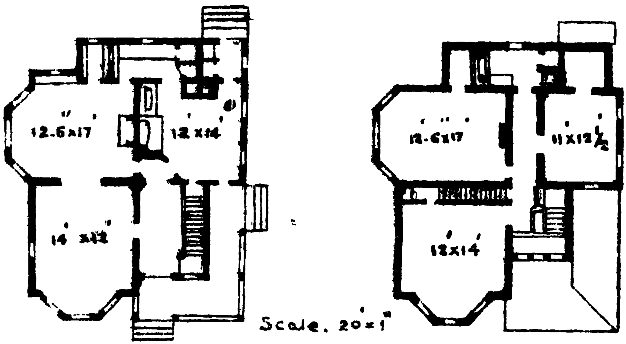

PLAN. NO.104
Scale 32'=1"
FIRST FLOOR
SECOND FLOOR
PLAN NO 105
Scale, 25'=1"

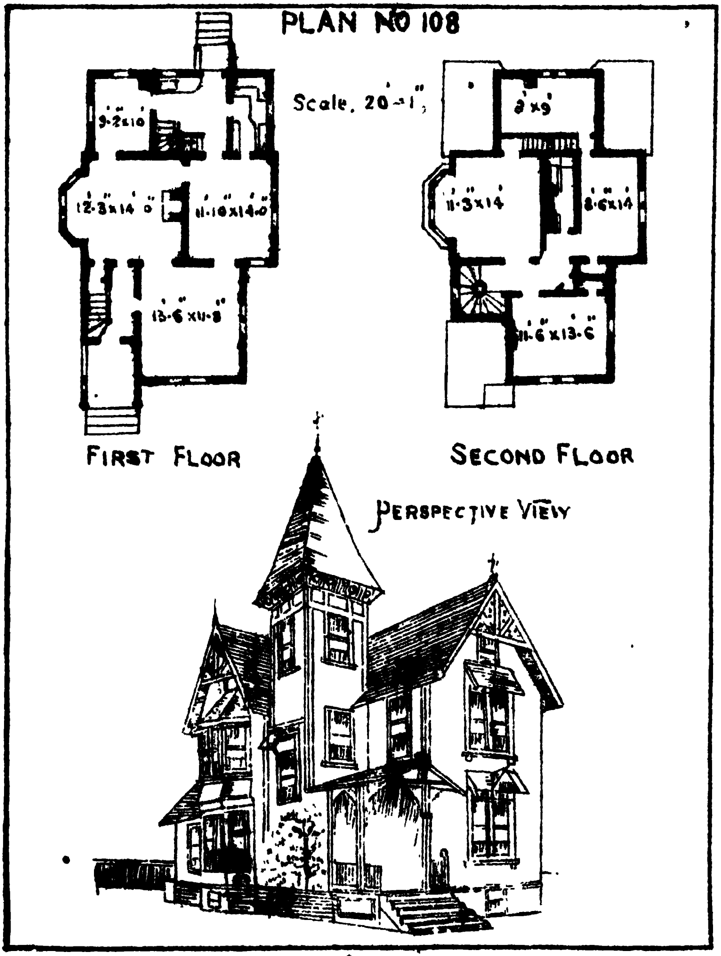
PLAN NO. 106

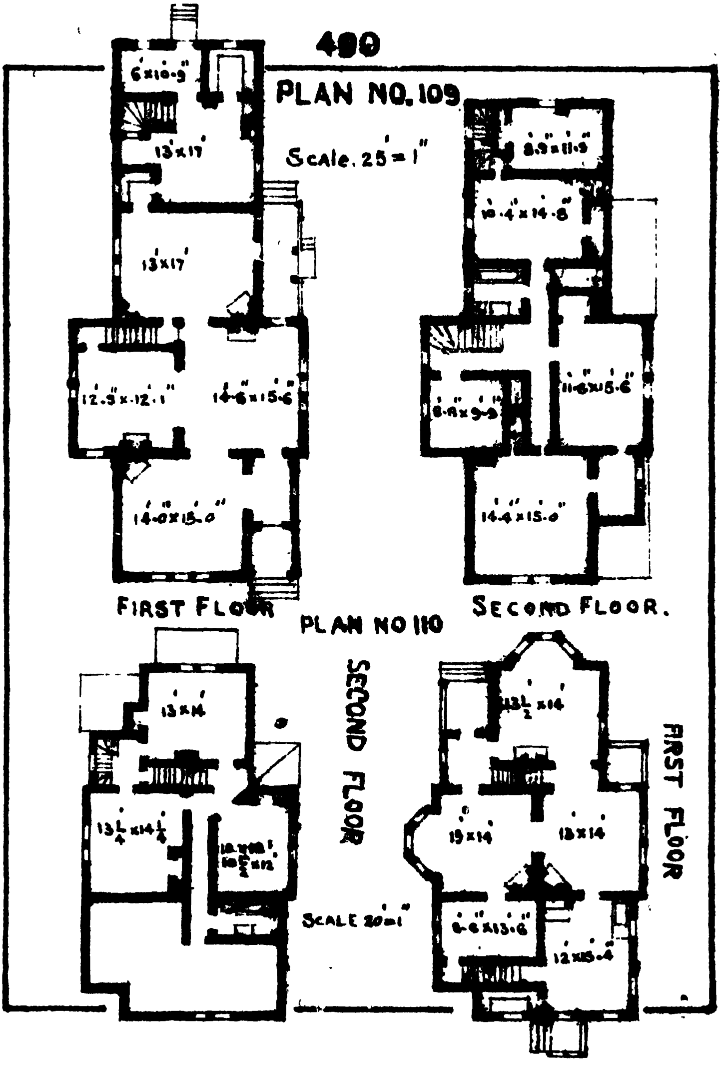


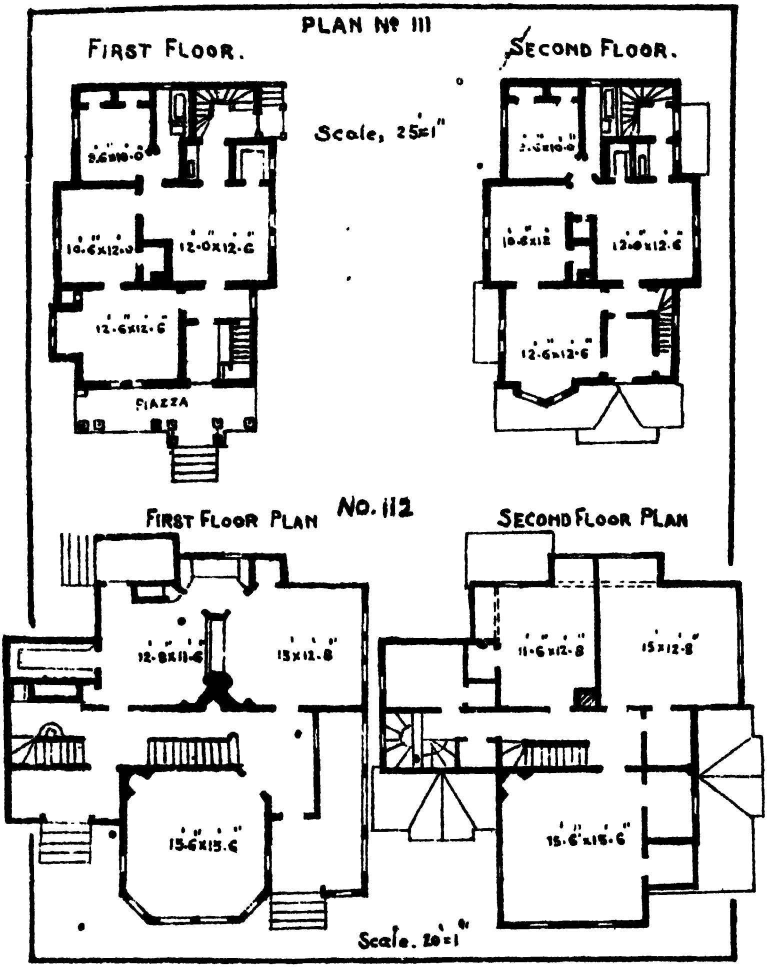
FIRST FLOOR. SECOND FLOOR.

PLAN NO 107

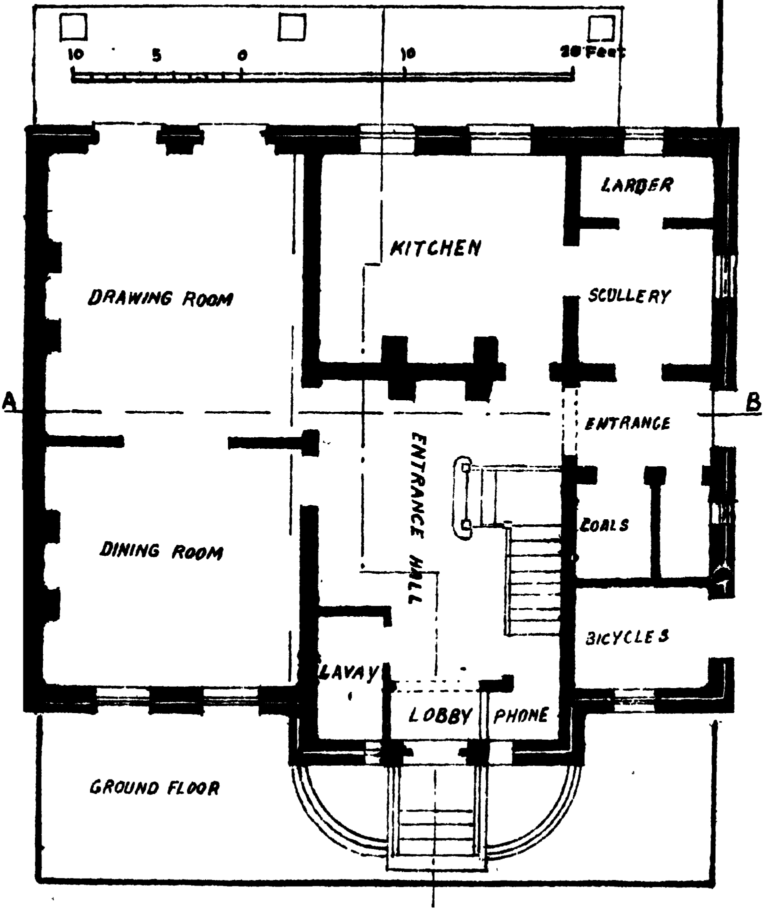


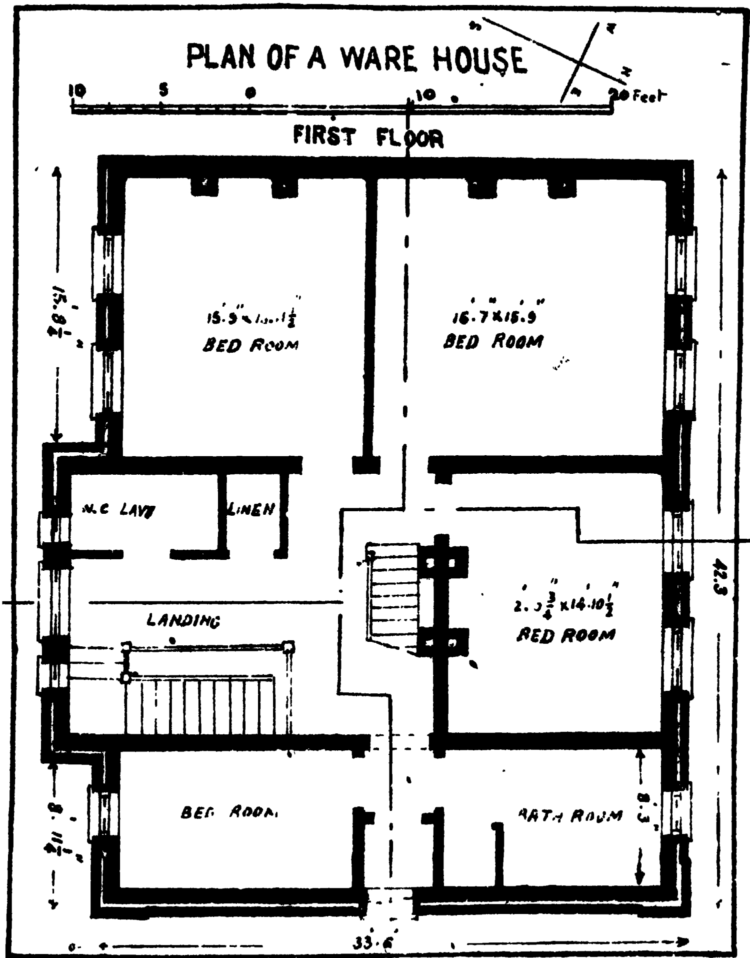

PLAN NO 108
Scale, 20'=1"
9-2x10
12-3x14-0
11-10x14-0
13-6x11-8
11-3x14
8-6x14
11-6x13-6
FIRST FLOOR
SECOND FLOOR
PERSPECTIVE VIEW

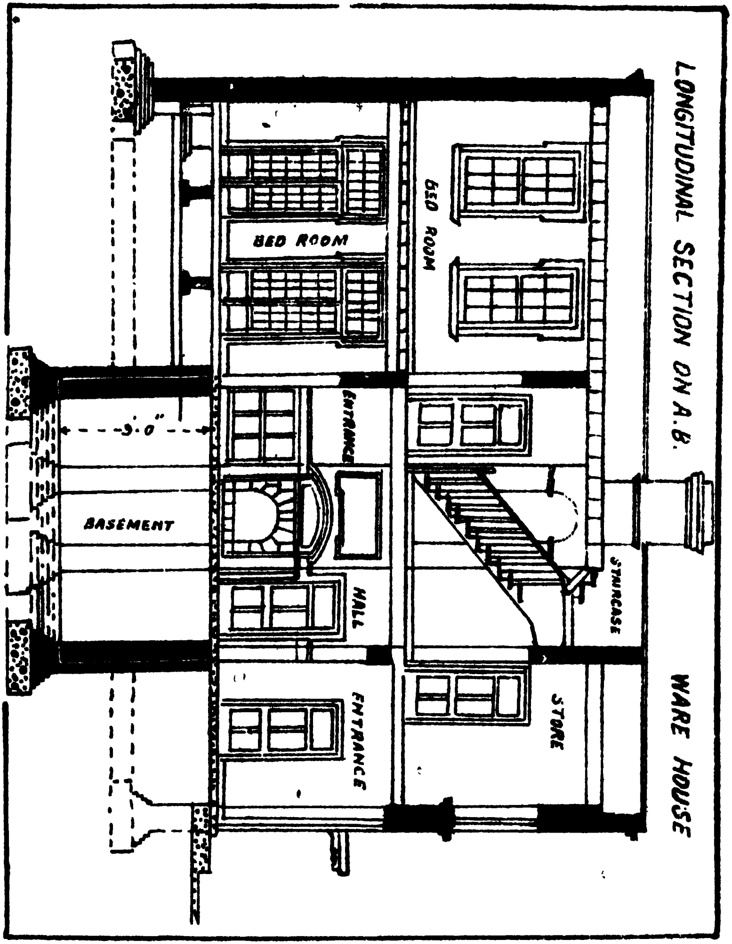

PLAN NO. 109
Scale. 25' = 1"
6'x10-9"
13'x17'
13'x17'
12-3"x12-1"
14-6"x15-6"
14-0"x15-0"
FIRST FLOOR
8-9"x11-9"
10-4"x14-6"
11-6"x15-6"
8-8"x9-9"
14-4"x15-0"
SECOND FLOOR.
PLAN NO 110
13x14
13 1/4 x 14 1/4
10 1/2 x 12
SECOND FLOOR
SCALE 20' = 1"
13 1/2 x 14
19x14
13x14
8-6"x13-6"
12x15-4
FIRST FLOOR

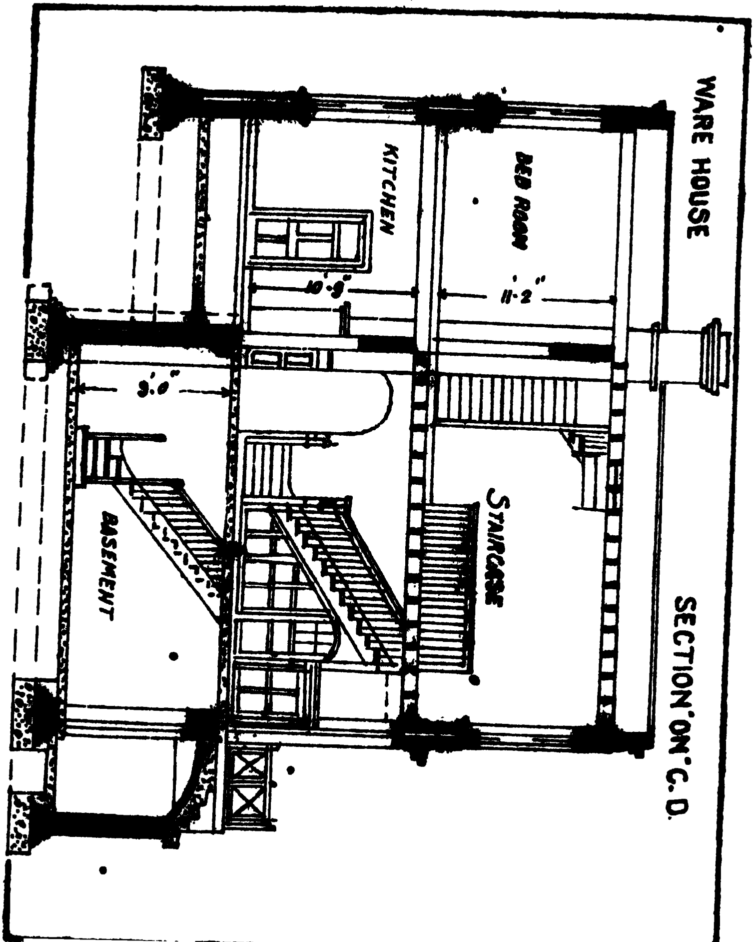

PLAN No. 111
FIRST FLOOR.
SECOND FLOOR.
Scale, 25=1"
9.6x10.0
10.6x12.0
12.0x12.6
12.6x12.6
PIAZZA
10.6x12
12.0x12.6
12.6x12.6
NO. 112
FIRST FLOOR PLAN
SECOND FLOOR PLAN
12.8x11.6
15x12.8
15.6x15.6
11.6x12.8
15x12.8
15.6x15.6
Scale. 20=1"

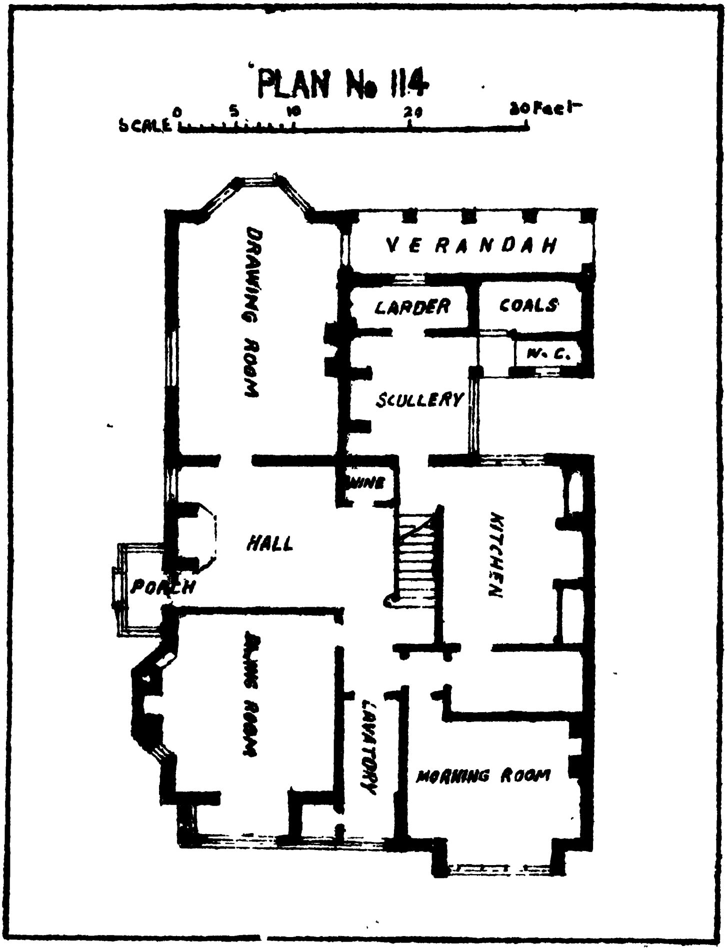
No.113 PLAN OF A WARE HOUSE

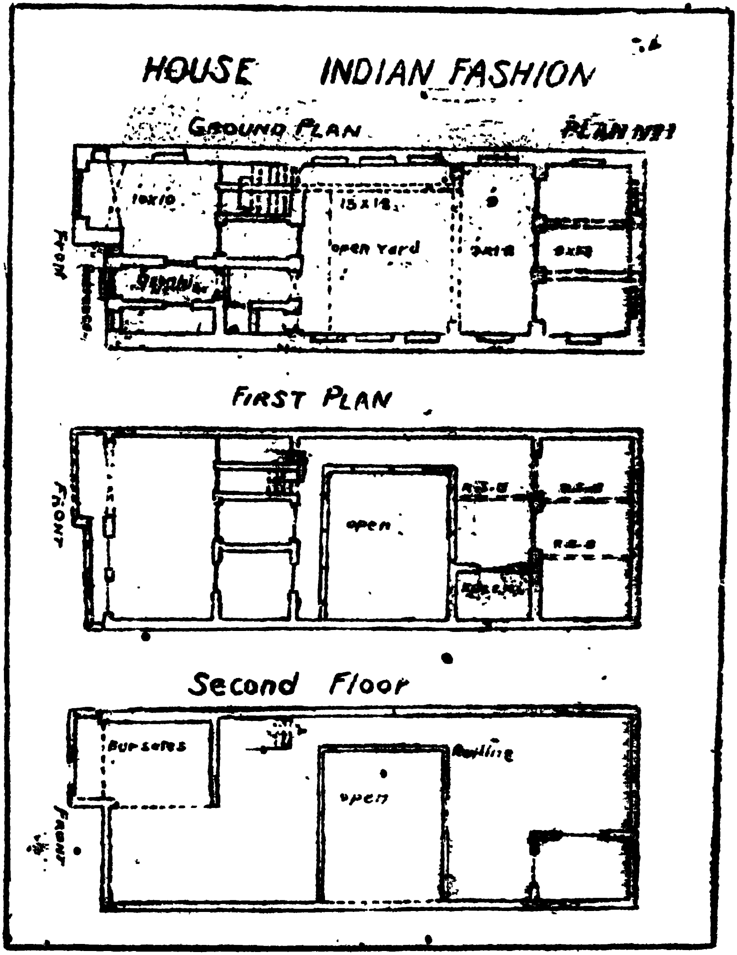


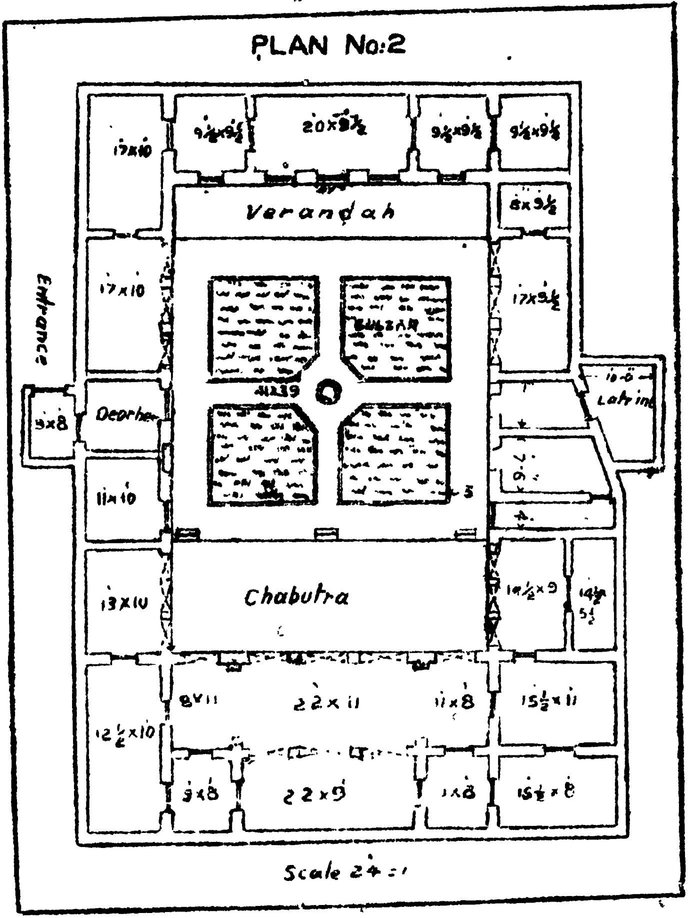

PLAN OF A WARE HOUSE
10
5
0
10
20 Feet
FIRST FLOOR
BED ROOM
16.7 x 15.9
BED ROOM
LINEN
LANDING
BED ROOM
BATH ROOM
42.3
33.6

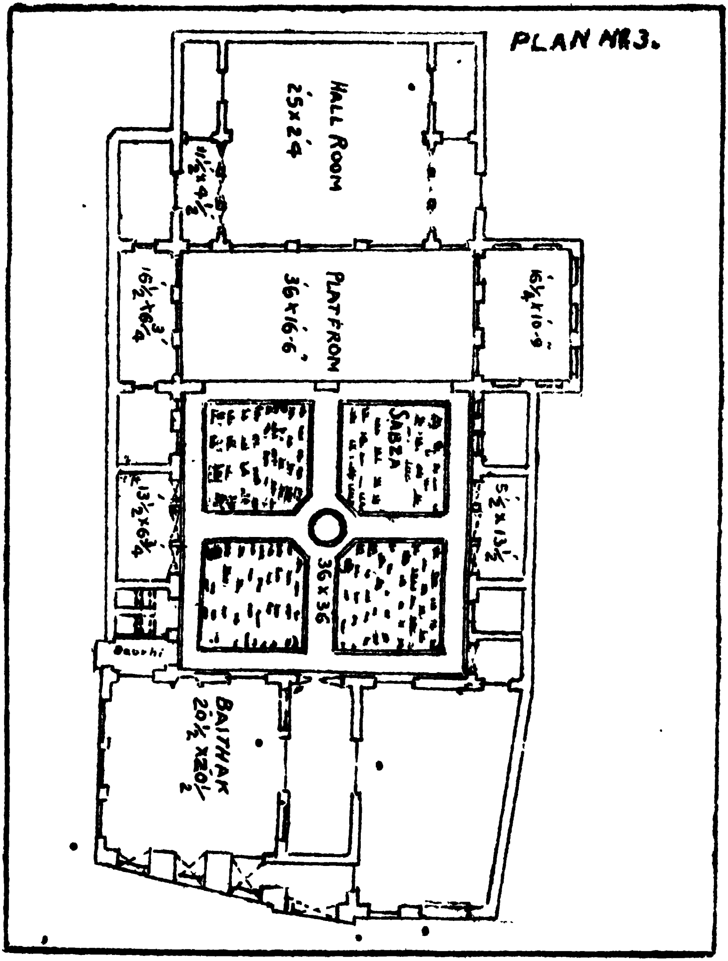

LONGITUDINAL SECTION ON A.B.
WARE HOUSE
BED ROOM
BED ROOM
ENTRANCE
BASEMENT
5'0"
HALL
STAIRCASE
STORE
ENTRANCE

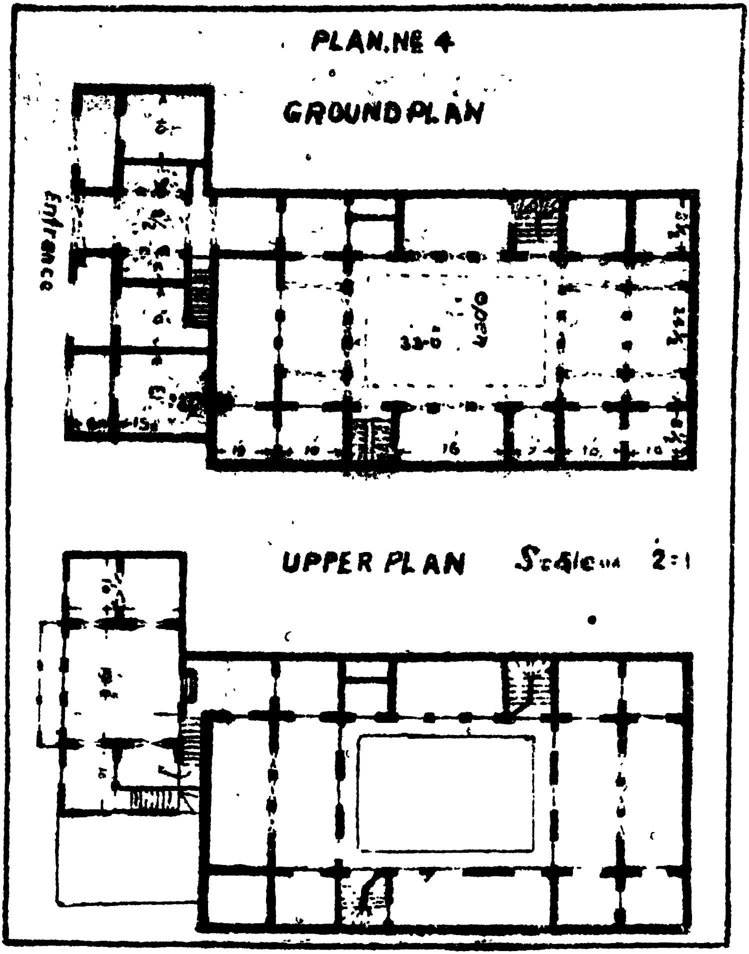

WARE HOUSE
KITCHEN
BED ROOM
10·9"
11·2"
9·0"
BASEMENT
STAIRCASE
SECTION ON C.D.


PLAN No 114
SCALE 0 5 10 20 30 Feet
VERANDAH
DRAWING ROOM
LARDER
COALS
W. C.
SCULLERY
WINE
HALL
KITCHEN
PORCH
LAVATORY
MORNING ROOM


HOUSE INDIAN FASHION
GROUND PLAN
15 x 18
open Yard
FRONT
FIRST PLAN
open
FRONT
Second Floor
Railing
open
FRONT

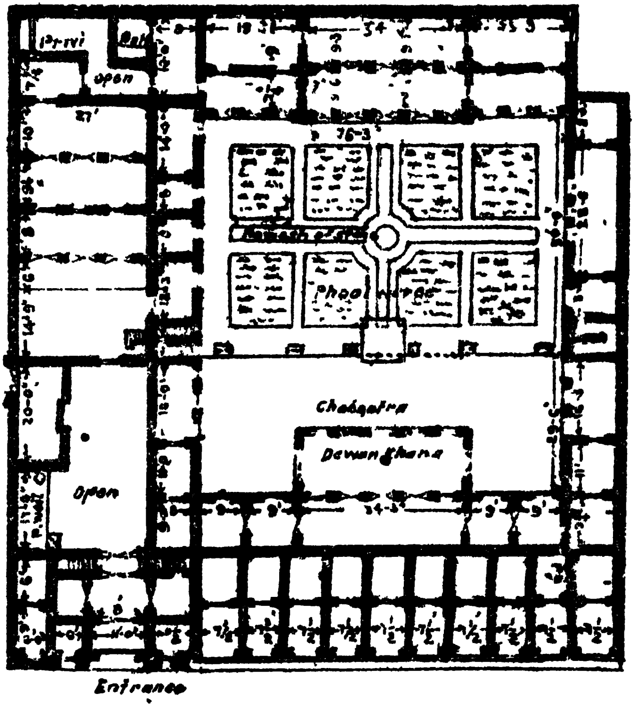

PLAN No:2
17x10
9½x9½
20x9½
9½x9½
9½x9½
8x9½
Verandah
17x10
17x9½
Entrance
GULZAR
9x8
Deorhe
Latrine
11x10
13x10
Chabutra
14½x9
14½
5½
8x11
22x11
11x8
15½x11
12½x10
9x8
22x9
15½x8
Scale 24:1


PLAN No.3.
HALL ROOM
25 x 24
PLATFROM
36 x 16-6
SABZA
36 x 36
Deorhi
BAITHAK
20½ x 20½

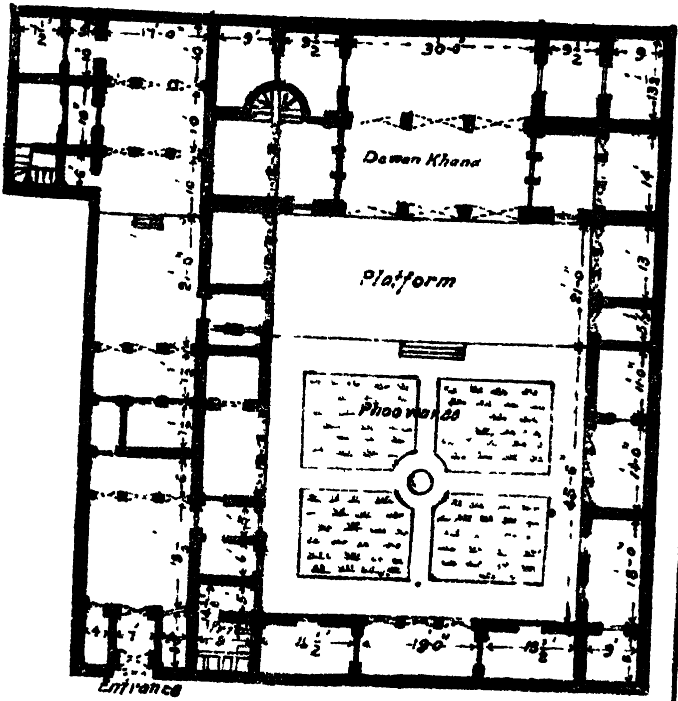

PLAN. No 4
GROUND PLAN
Entrance
open
33-0
UPPER PLAN

PLAN No. 5

Scale 40'=1"



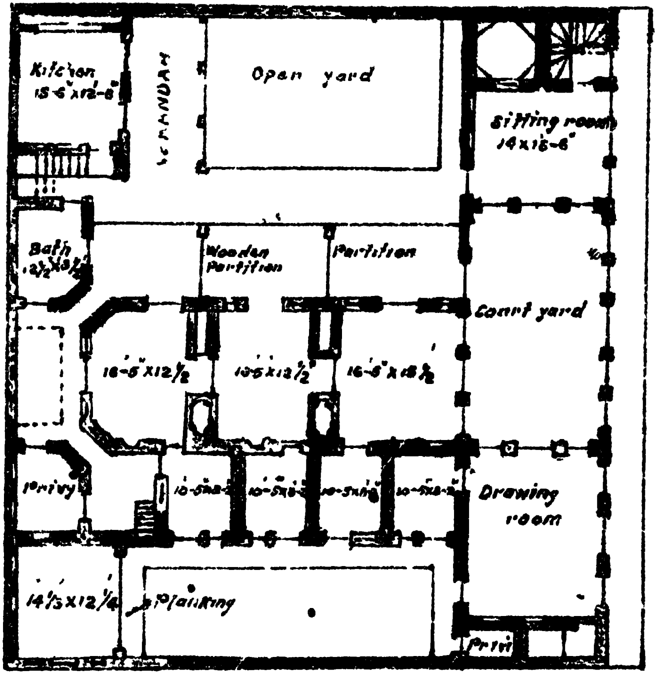
PLAN No. 6

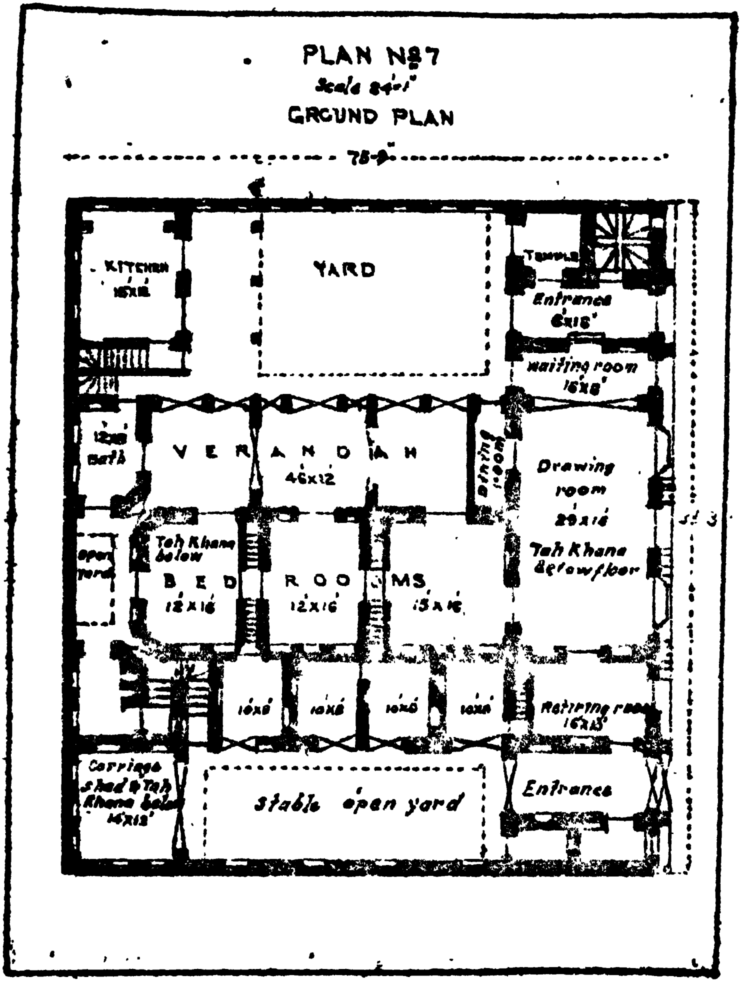


Scale 24'=1"

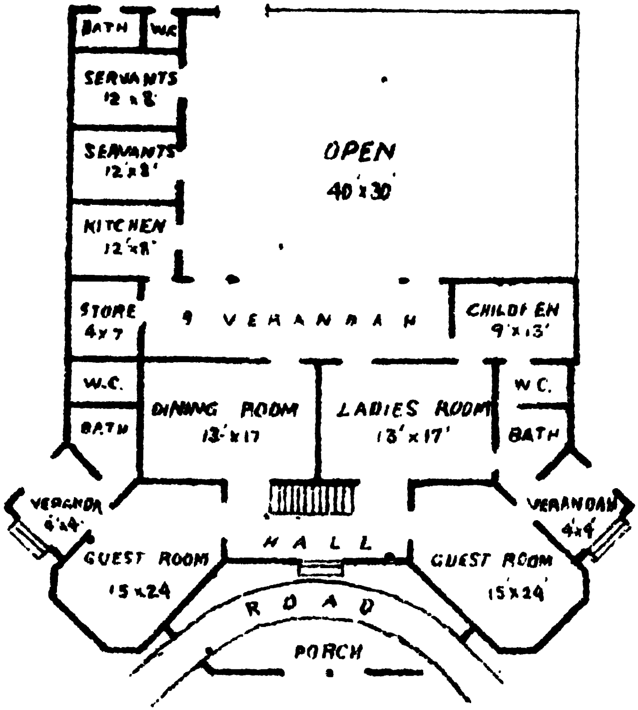
PLAN No. 7
Scale 24'=1"

UPPER PLAN



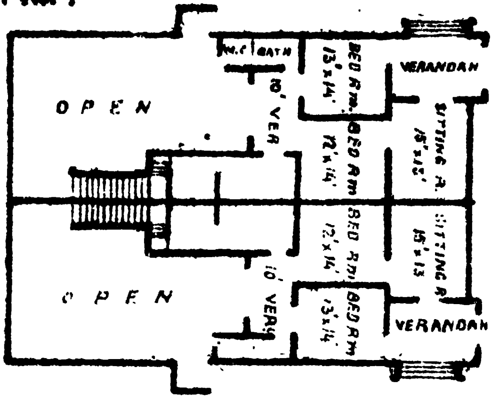

PLAN No 7
Scale 24=1"
GROUND PLAN
75-9"
KITCHEN
16X12
YARD
Temple
Entrance
6X15'
waiting room
16X8'
12X8
bath
VERANDAH
46X12
Dining room
Drawing room
29X16
open yard
Tah Khana below
BED ROOMS
12X16
12X16
15X16
Tah Khana Below floor
16X8
10X8
10X8
10X8
Retiring room
16X15
Carriage shed & Tah Khana below
16X12'
Stable open yard
Entrance

PLAN No. 8

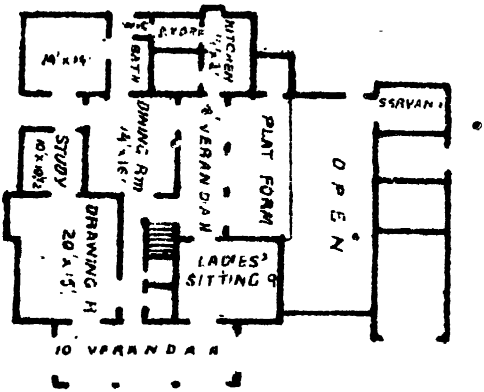


SCALE 20' = 1"

PLAN No. 9 SCALE 30'-1"



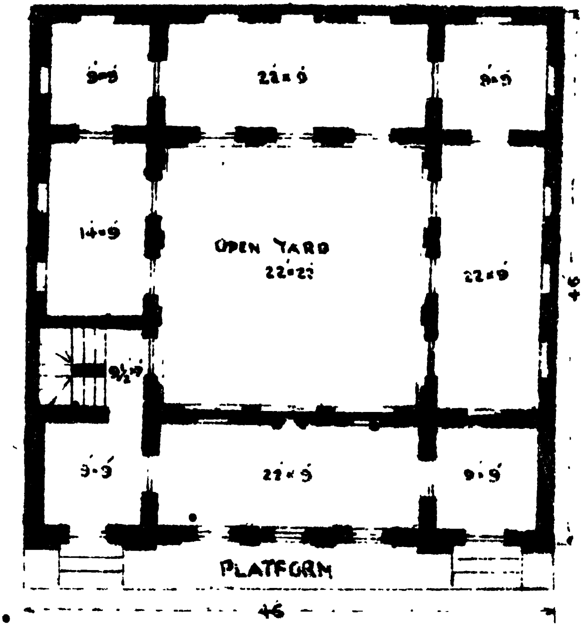
PLAN No. 10 SCALE 20'-1"



PLAN NR 11

Scale. 16 = 1"

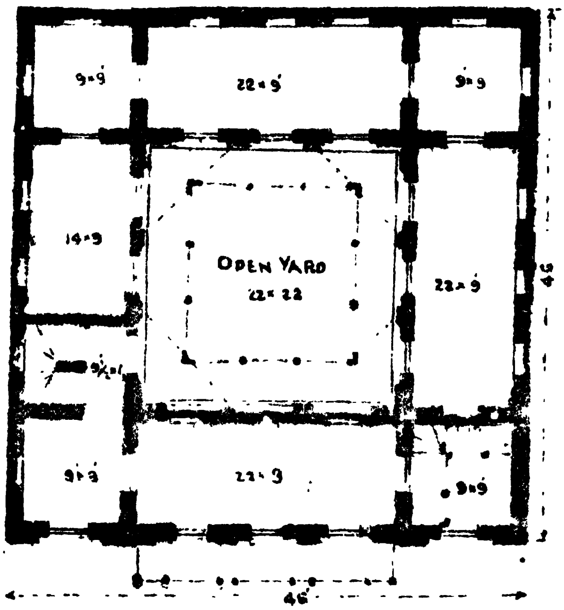
GROUND PLAN.

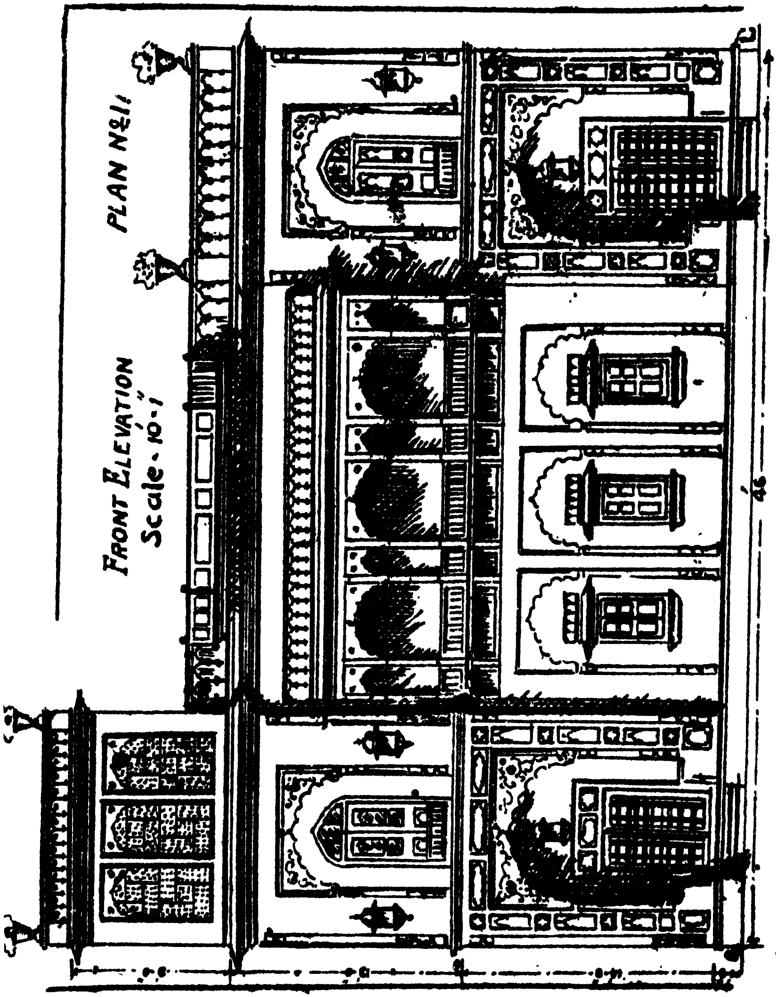


PLAN. No 11

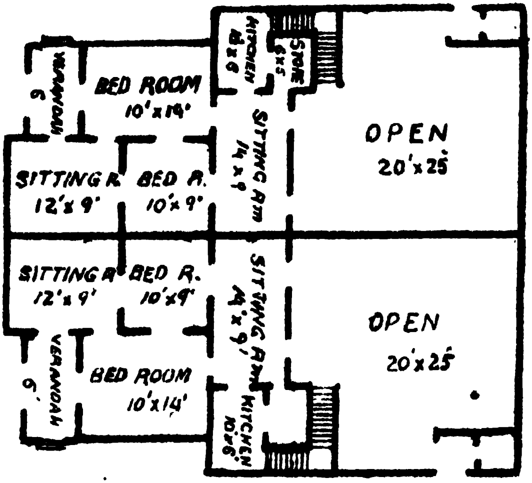
Scale. 16 = 1"

UPPER PLAN




PLAN No 1
FRONT ELEVATION
Scale · 10'-1"
46

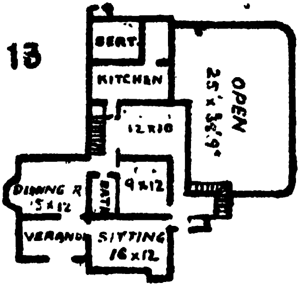
PLAN No. 12



SCALE

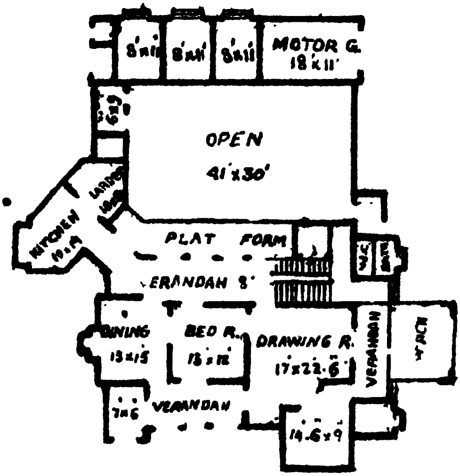
PLAN No. 13

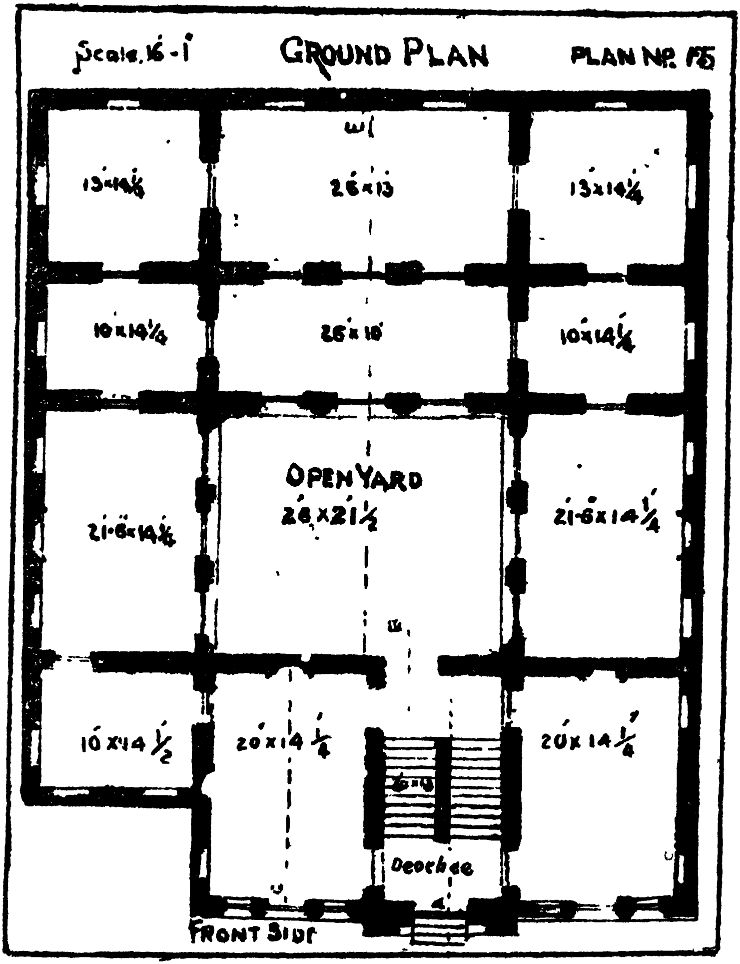
SCALE 40'=1"

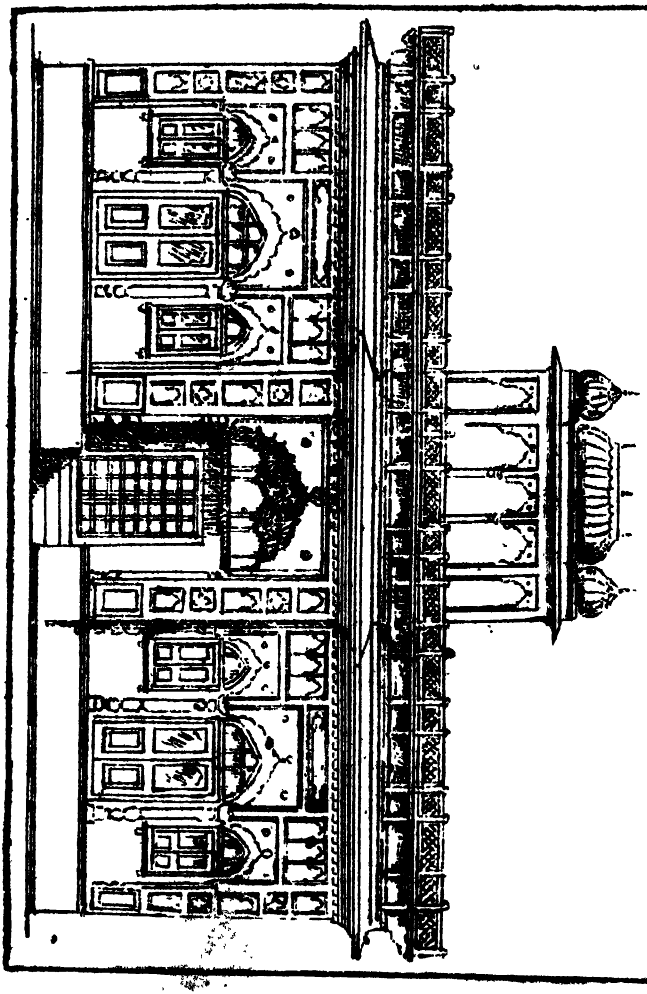


PLAN No. 14

SCALE 32'=1"

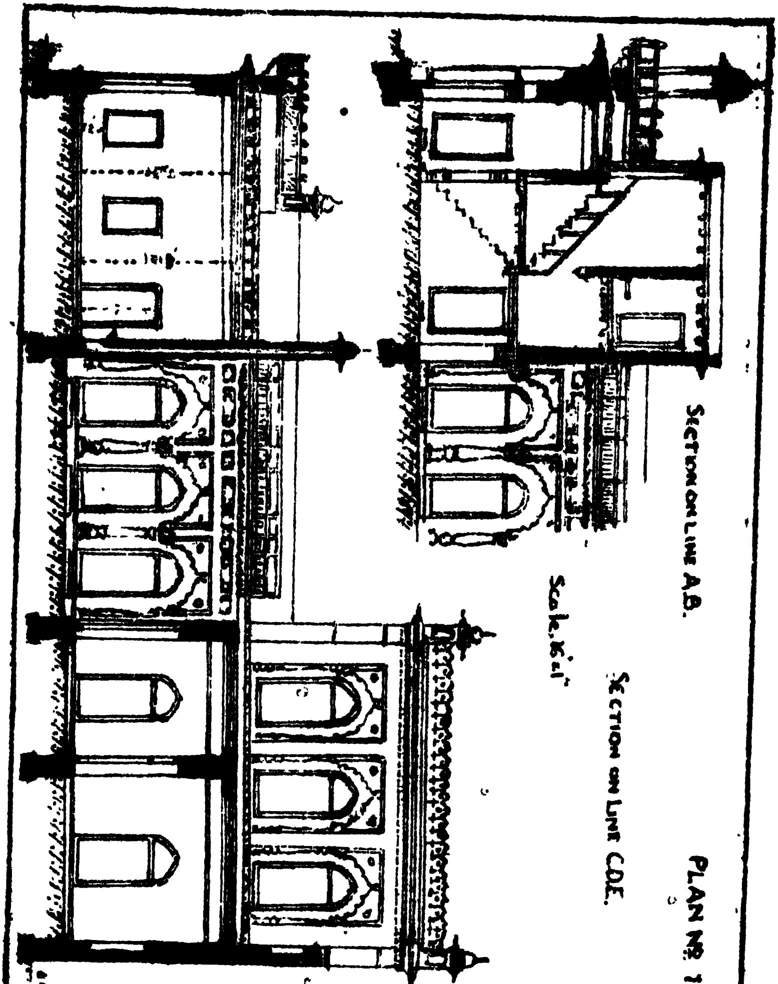



Scale 16-1
GROUND PLAN
PLAN No. 15
13×14½
26×13
13×14¼
10×14½
26×10
10×14¼
OPEN YARD
26×21½
21-6×14½
21-6×14¼
10×14½
20×14¼
20×14¼
Deorhee
FRONT SIDE



PLAN No. 15

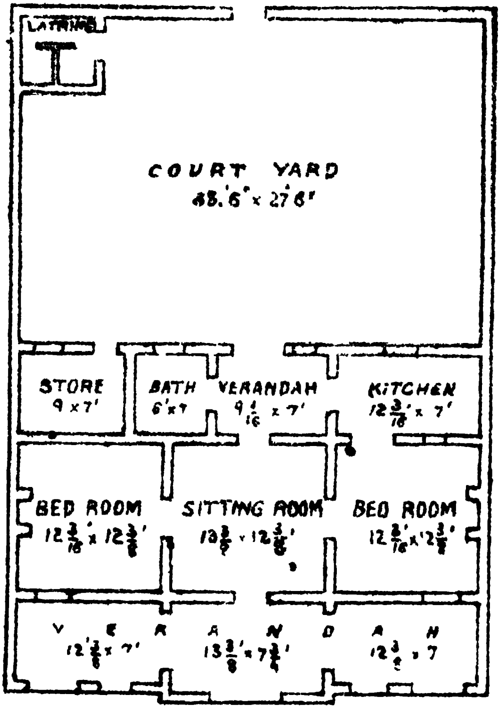
ELEVATION


SECTION ON LINE A.B.
SECTION ON LINE C.D.E.
PLAN No. 13

PLAN No. 16

RESIDENCE FOR INDIAN CLERKS

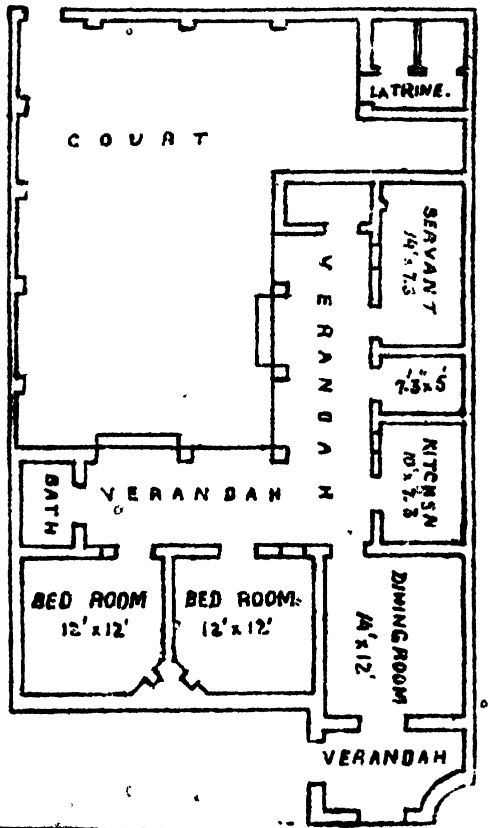
SCALE 16' = 1"

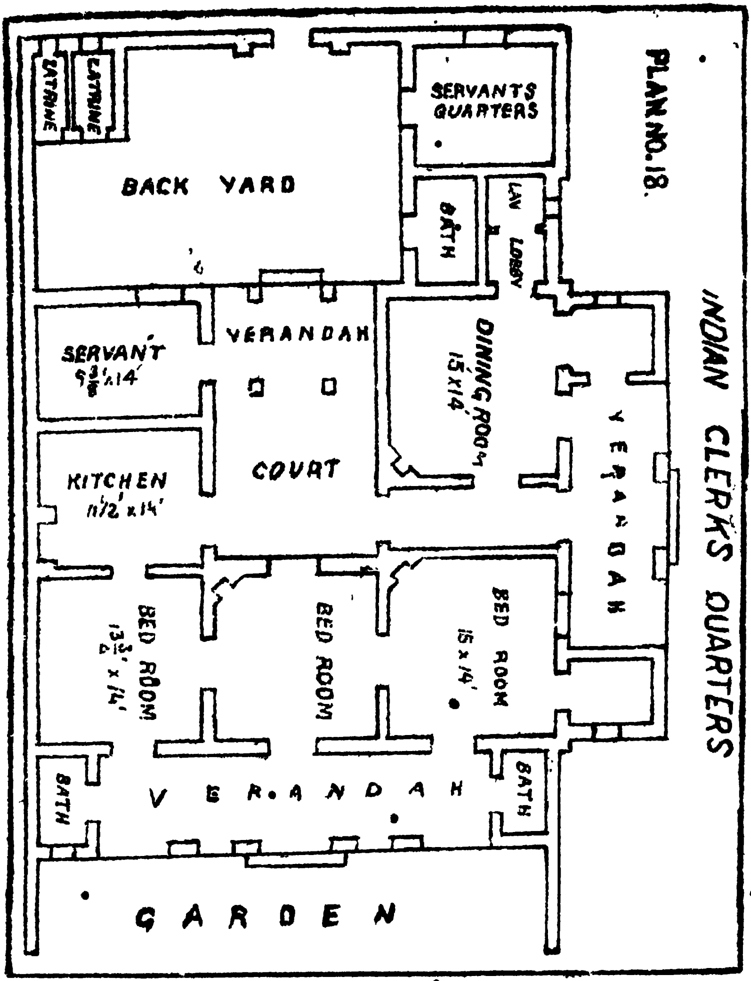


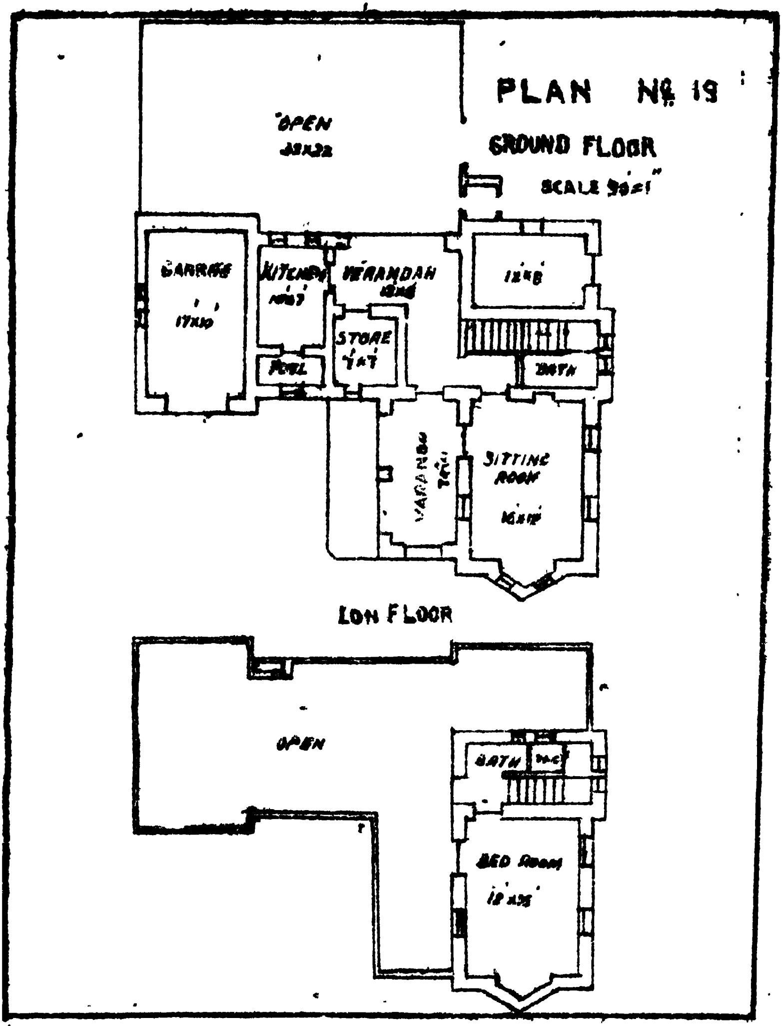
PLAN No. 17

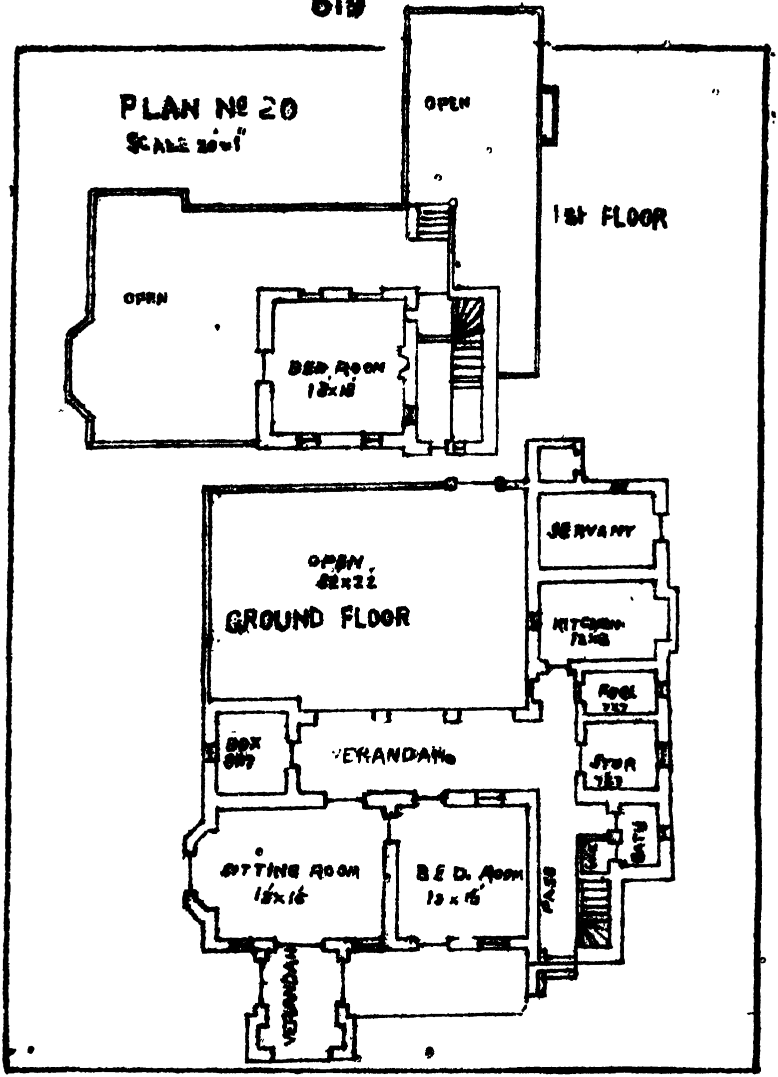
INDIAN CLERKS QUARTERS

SCALE 16'=1"

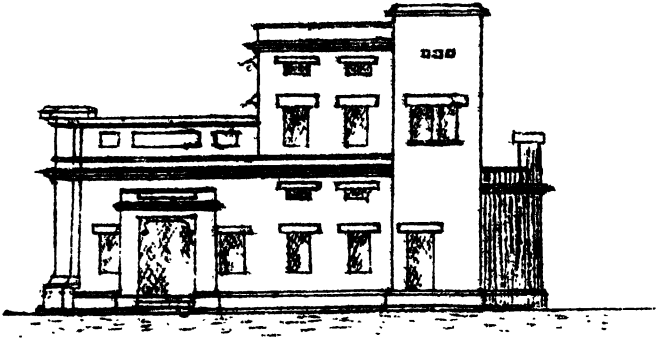



PLAN NO. 18.
INDIAN CLERK'S QUARTERS
LATRINE
LATRINE
SERVANTS QUARTERS
BACK YARD
BATH
LAV
LOBBY
VERANDAH
SERVANT 9 3/16' x 14'
DINING ROOM 15' x 14'
COURT
KITCHEN 11 1/2' x 14'
VERANDAH
BED ROOM 13 3/4' x 14'
BED ROOM
BED ROOM 15' x 14'
BATH
VERANDAH
BATH
GARDEN

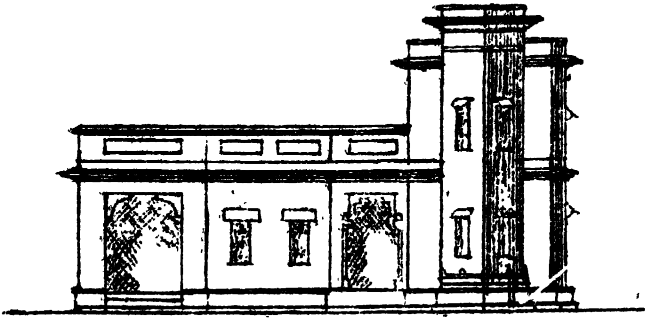

PLAN No 19
GROUND FLOOR
SCALE 30=1"
OPEN
GARRIAGE
17x10
KITCHEN
VERANDAH
STORE
FUEL
BATH
SITTING ROOM
LOW FLOOR
OPEN
BATH
W.C.
BED ROOM


PLAN No 20
OPEN
1st FLOOR
OPEN
BED ROOM
OPEN
GROUND FLOOR
SERVANT
KITCHEN
STOR
BATH
BOX
VERANDAH
SITTING ROOM
BED. ROOM
PASS
VERANDAH

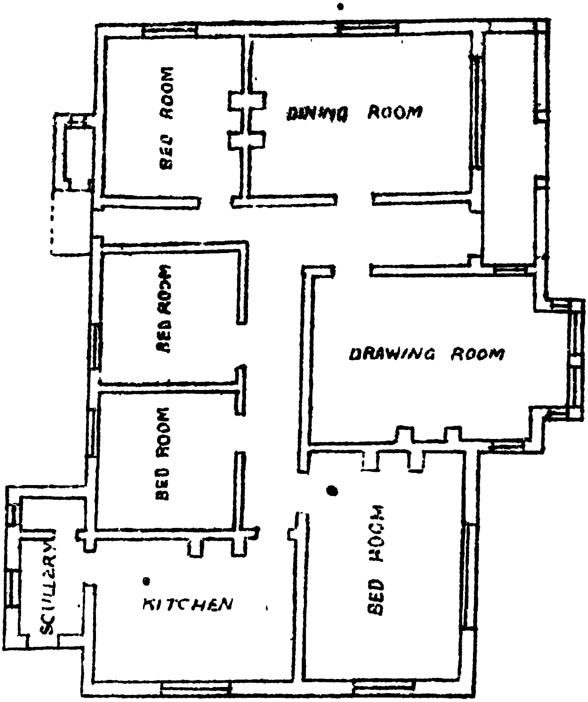
ELEVATION PLAN No. 20



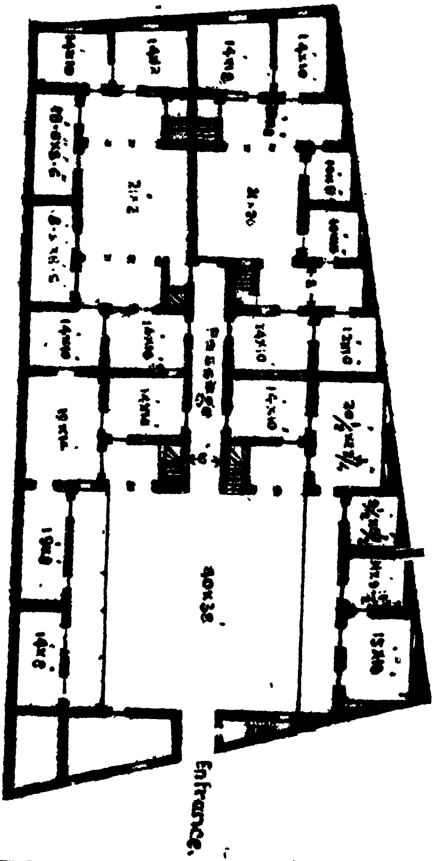
ELEVATION PLAN No. 13



PLAN No. 21

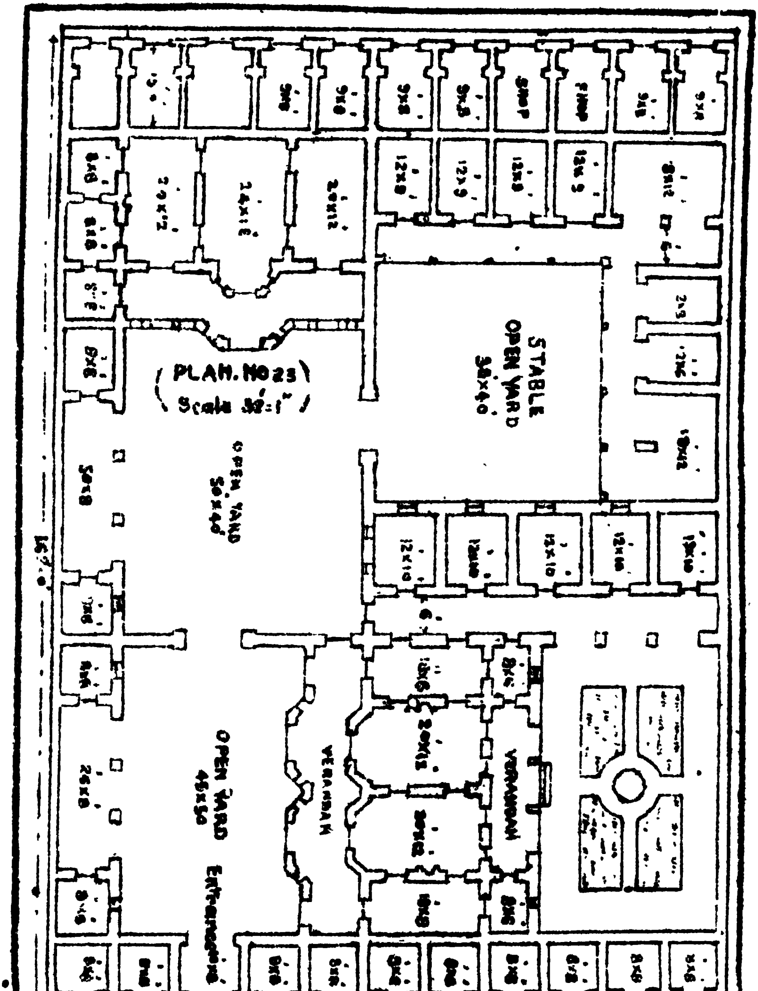

BED ROOM
DINING ROOM
BED ROOM
DRAWING ROOM
BED ROOM
BED ROOM
SCULLERY
KITCHEN

PLAN No 22



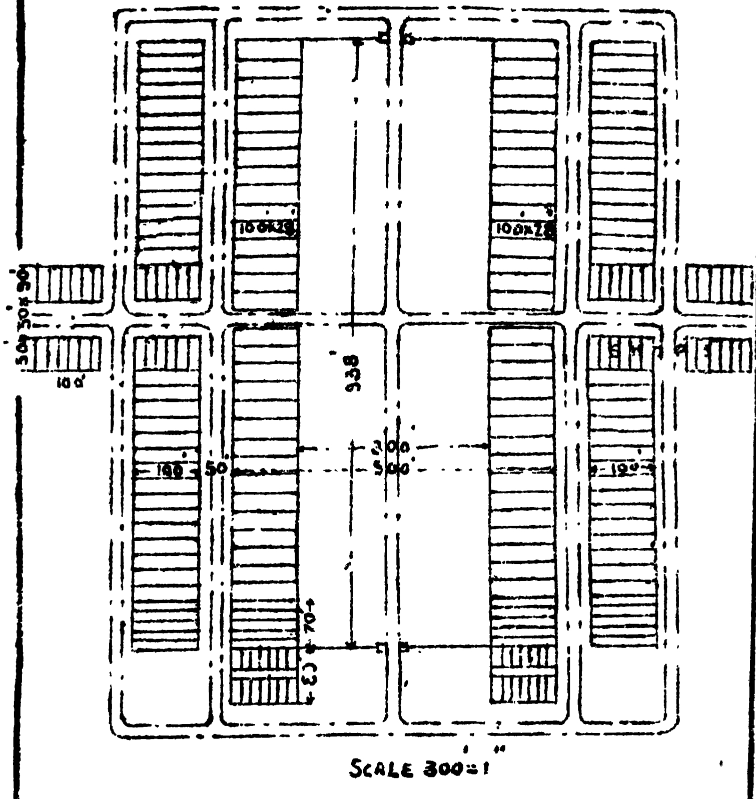
GROUND PLAN OF A KATREE.

Scale 36=1"


PLAN. NO 25
Scale 32'=1"
OPEN YARD
STABLE
OPEN YARD
VERANDAH
VERANDAH
OPEN YARD
Entrance

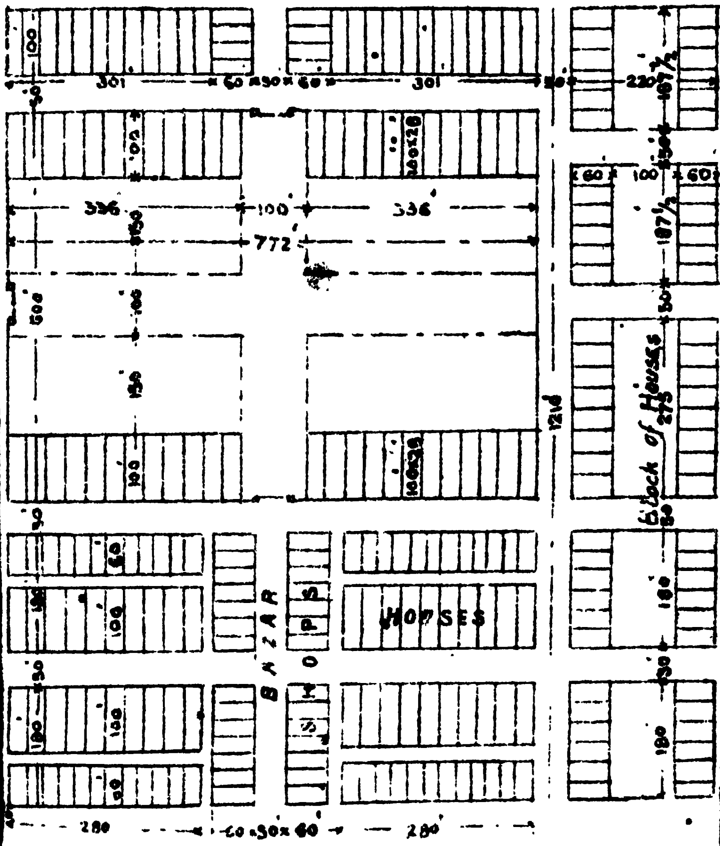
PLAN No. 24

PLAN FOR A MANDEE.



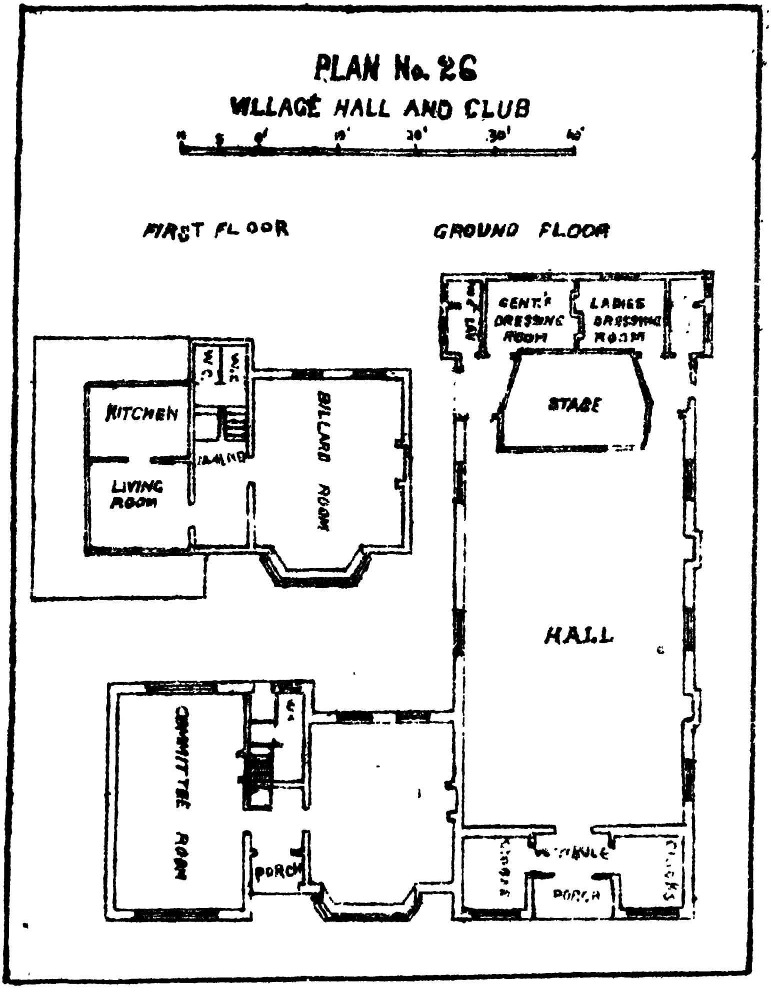
SCALE 300=1"

ANOTHER PLAN FOR A MANDEE.



SCALE 300' = 1"

PLAN No. 25

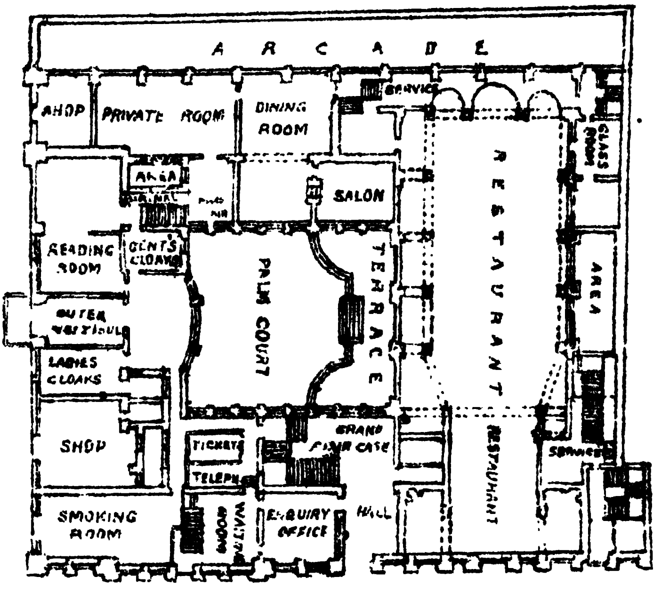

PLAN No. 26
VILLAGE HALL AND CLUB
FIRST FLOOR
GROUND FLOOR
KITCHEN
LIVING ROOM
BILLARD ROOM
W.C.
GENT.S DRESSING ROOM
LADIES DRESSING ROOM
STAGE
HALL
COMMITTEE ROOM
PORCH
CLOAKS
PORCH

PLAN No. 27

PLAN OF A HOTEL

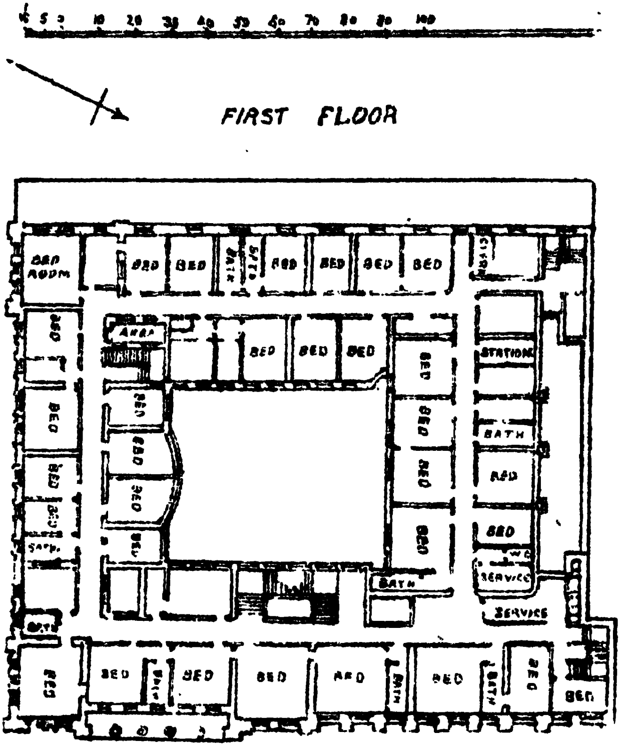
10' 5 10 20 30 40 50 60 70 80 90 100' 150'

GROUND FLOOR



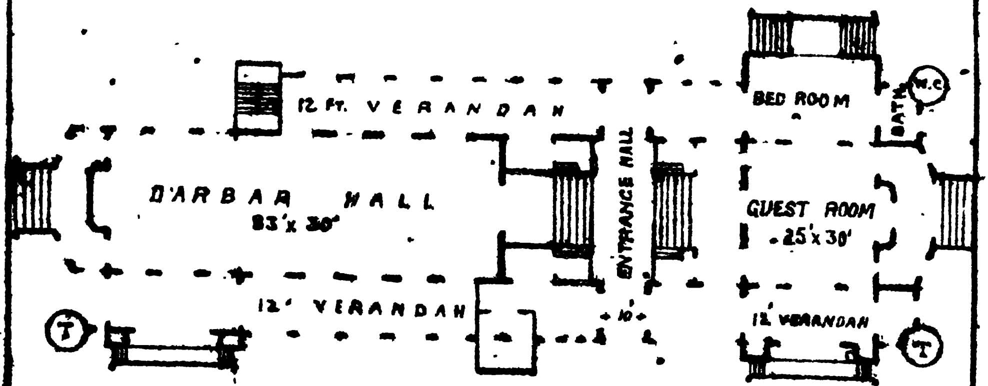
PLAN No. 27

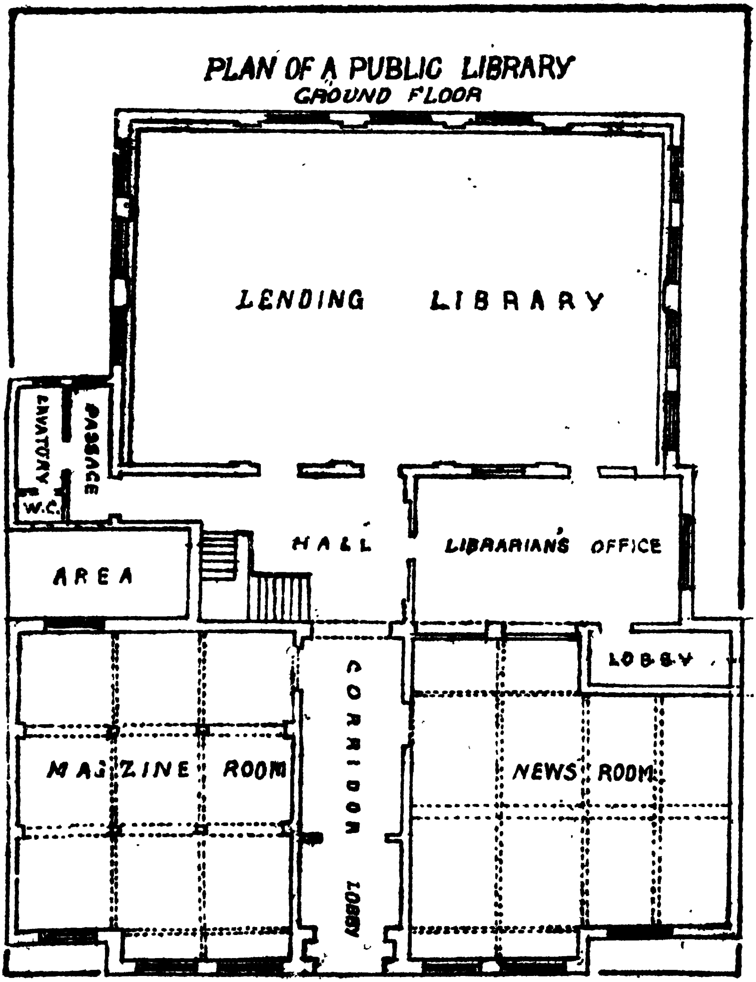
PLAN OF A HOTEL

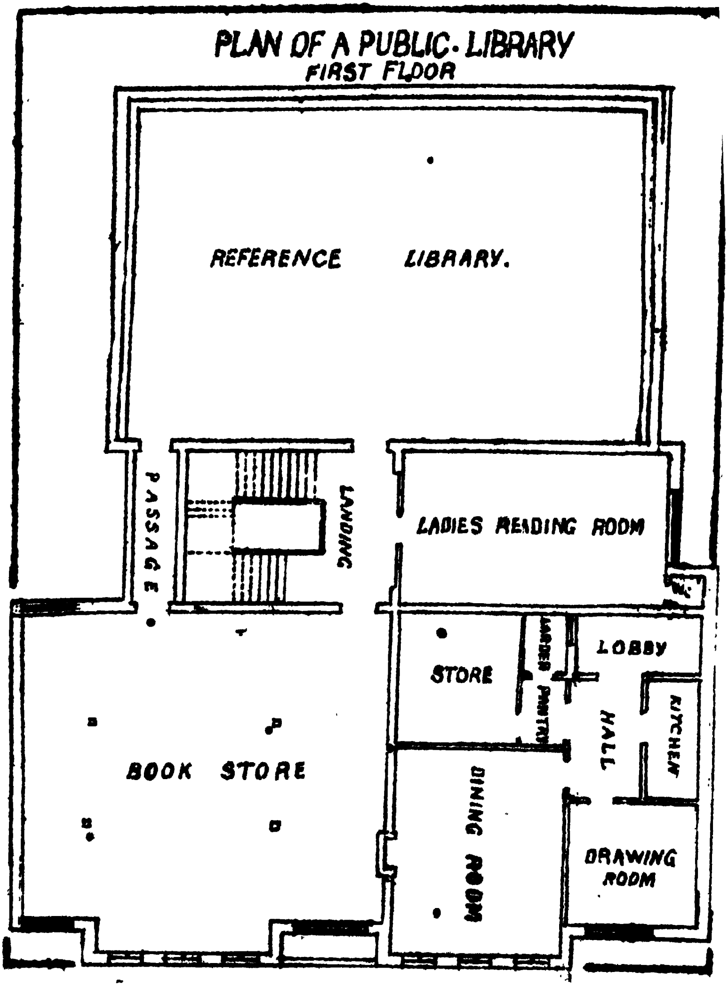


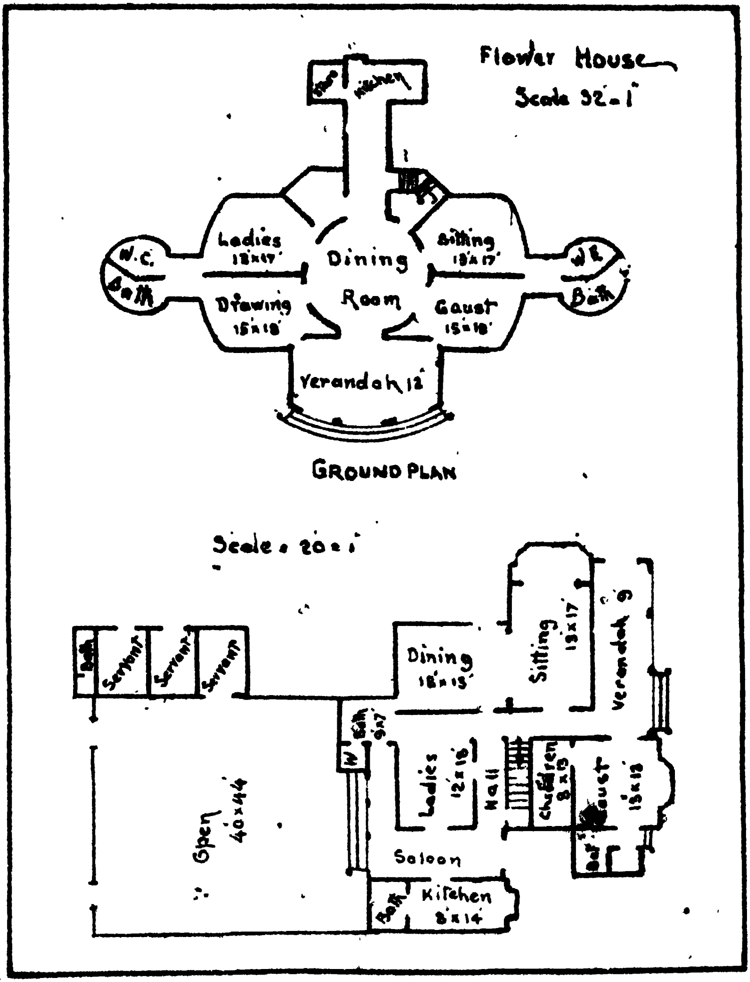
PLAN OF A DARBAR HALL

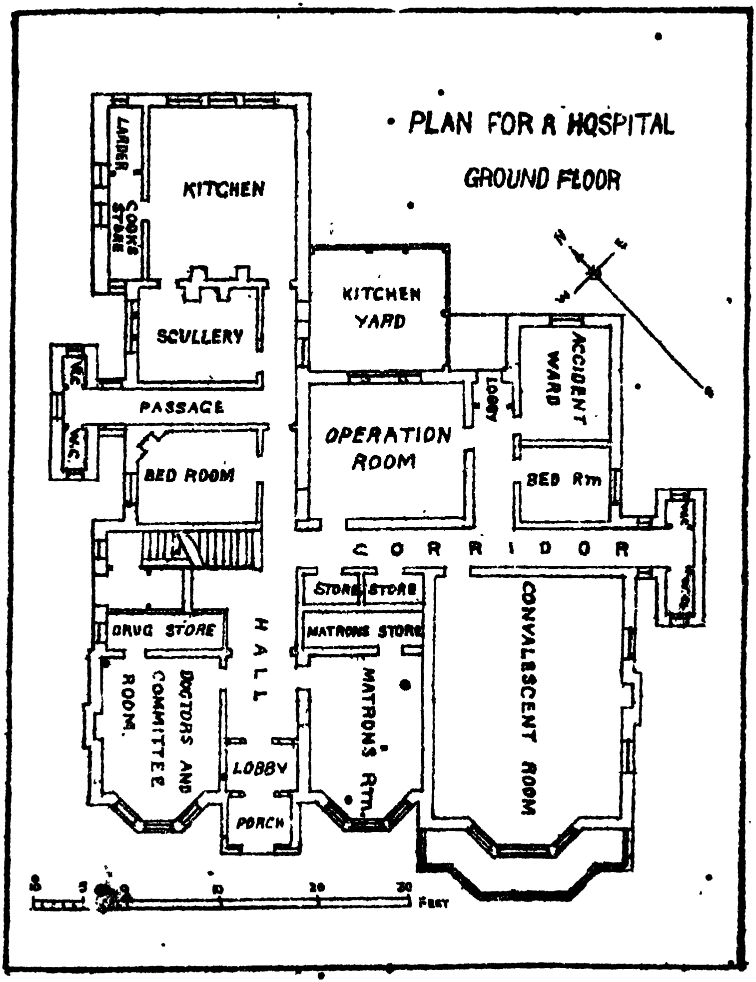
SCALE 40'=1"

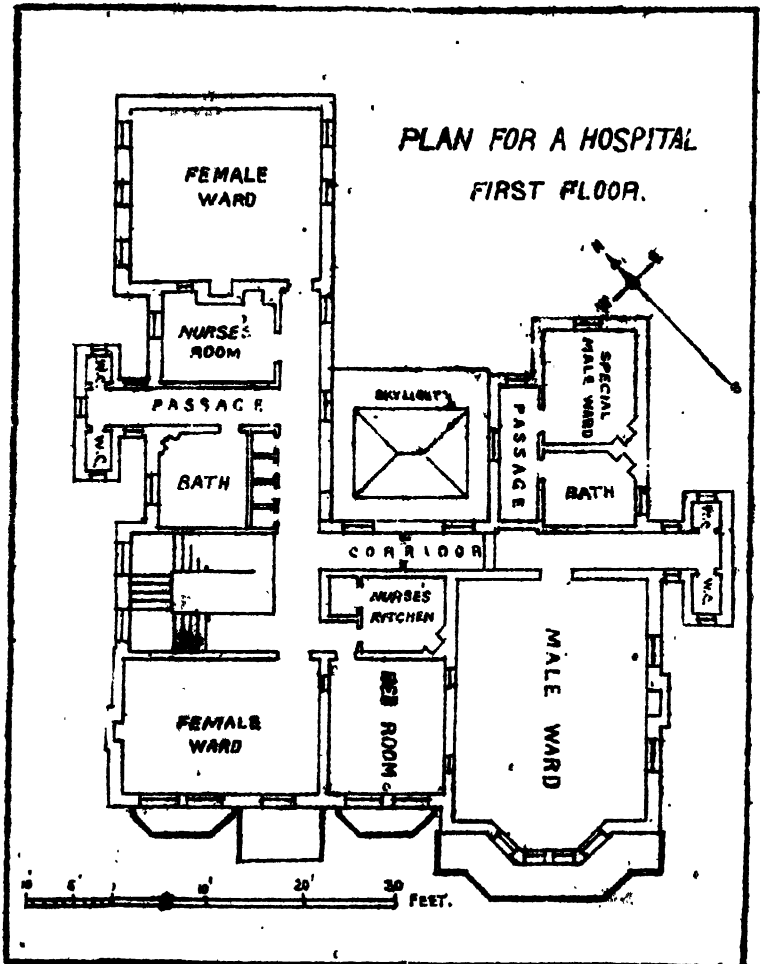


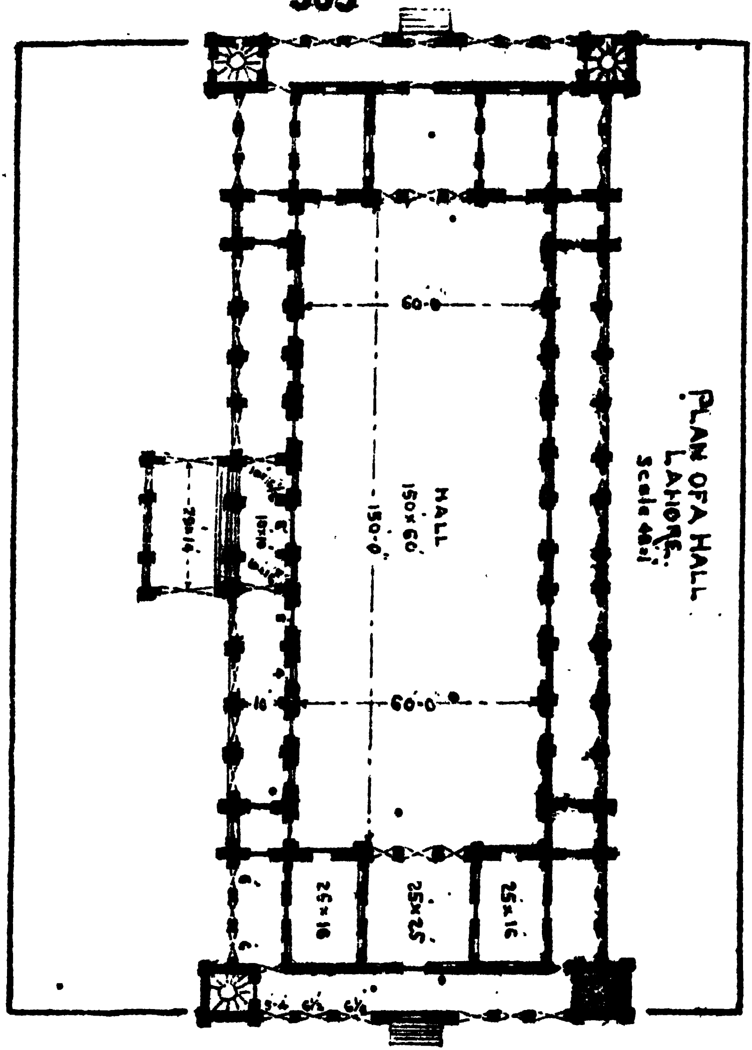

PLAN OF A PUBLIC LIBRARY
GROUND FLOOR
LENDING LIBRARY
LAVATORY
PASSAGE
W.C.
AREA
HALL
LIBRARIAN'S OFFICE
LOBBY
MAGAZINE ROOM
CORRIDOR
LOBBY
NEWS ROOM

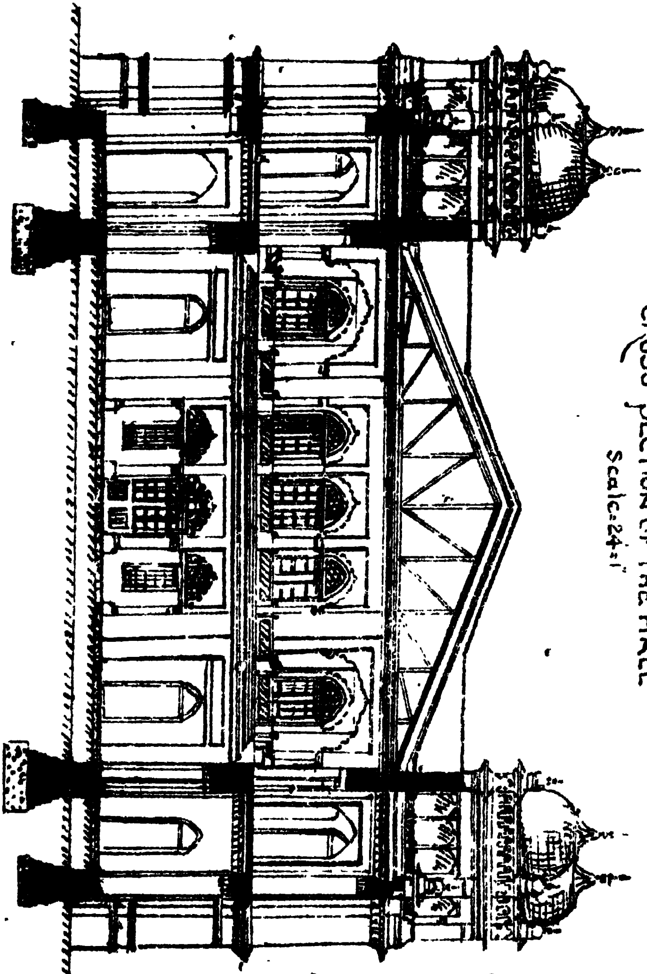

PLAN OF A PUBLIC LIBRARY
FIRST FLOOR
REFERENCE LIBRARY.
PASSAGE
LANDING
LADIES READING ROOM
STORE
LARDER
PANTRY
LOBBY
HALL
KITCHEN
BOOK STORE
DINING ROOM
DRAWING ROOM


Flower House
Scale 32=1
Kitchen
Ladies
12x17
Dining
Room
Sitting
13x17
W.C.
Bath
Drawing
15x18
Gaust
15x18
Verandah 12
GROUND PLAN
Scale = 20=1
Bath
Servant
Servant
Servant
Dining
18x15
Sitting
13x17
Verandah 9
Bath
9x7
W
Ladies
12x16
Hall
Children
8x13
Gaust
15x18
Open
40x44
Saloon
Kitchen
8x14
Bath

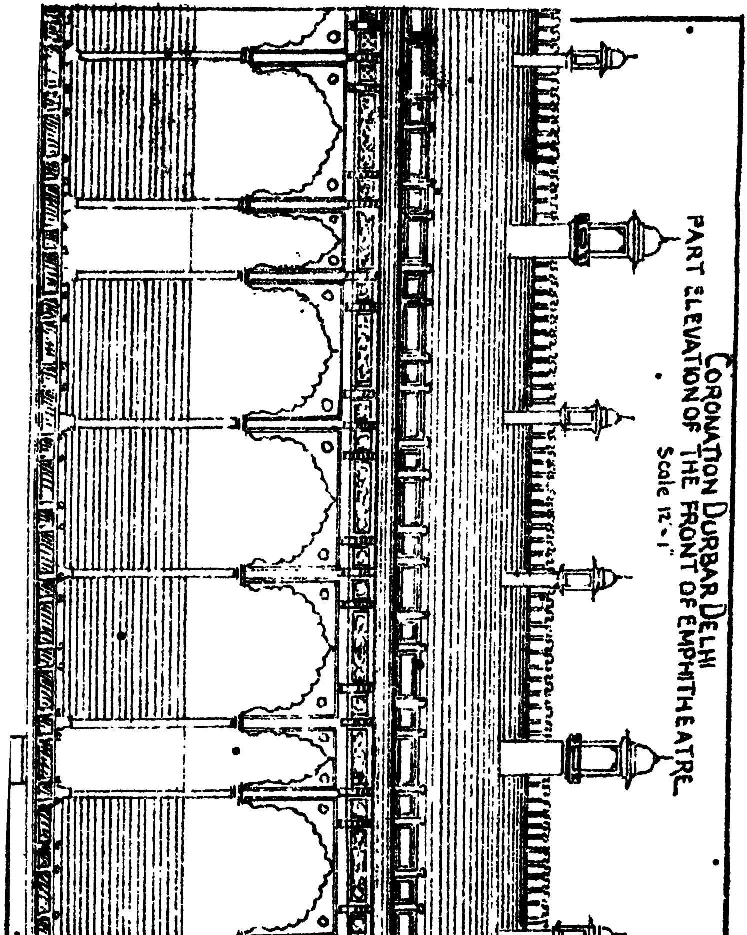

PLAN FOR A HOSPITAL
GROUND FLOOR
LARDER
COOKS STORE
KITCHEN
SCULLERY
KITCHEN YARD
ACCIDENT WARD
LOBBY
W.C.
PASSAGE
W.C.
OPERATION ROOM
BED ROOM
BED Rm
CORRIDOR
STORE
STORE
DRUG STORE
HALL
MATRONS STORE
DOCTORS AND COMMITTEE ROOM.
MATRONS Rm.
CONVALESCENT ROOM
LOBBY
PORCH
0
10
20
30
FEET

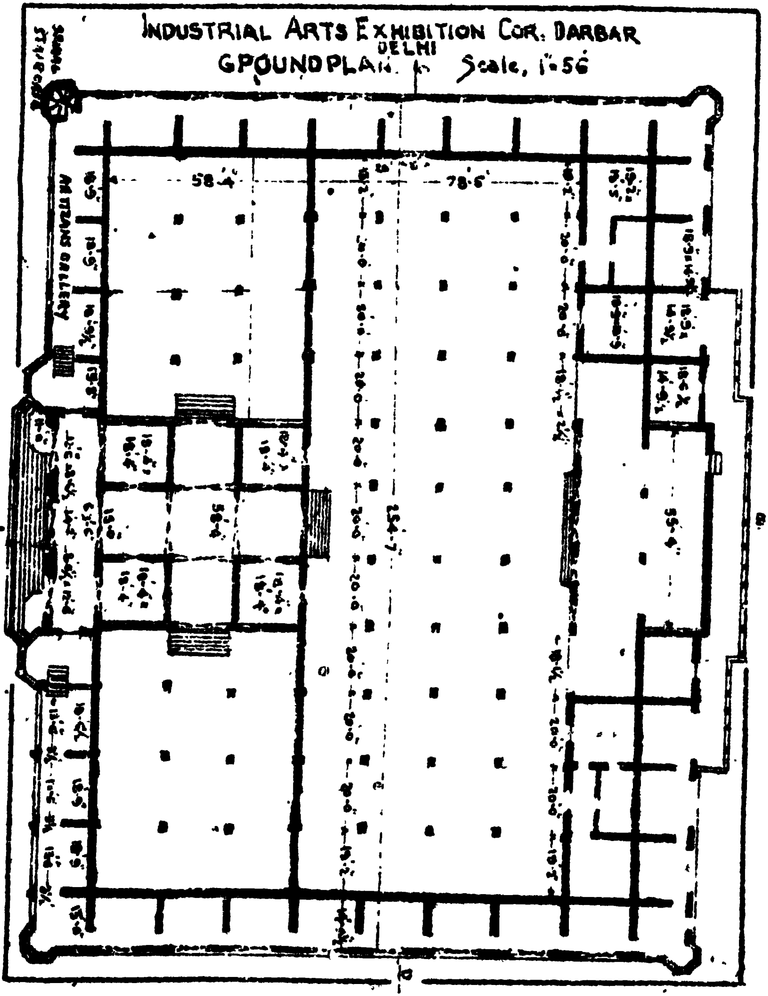

PLAN FOR A HOSPITAL
FIRST FLOOR.
FEMALE WARD
NURSES ROOM
W.C.
PASSAGE
W.C.
BATH
SKYLIGHT
PASSAGE
SPECIAL MALE WARD
BATH
W.C.
CORRIDOR
NURSES KITCHEN
W.C.
MALE WARD
FEMALE WARD
ROOM
10 5 0 10 20 30 FEET.

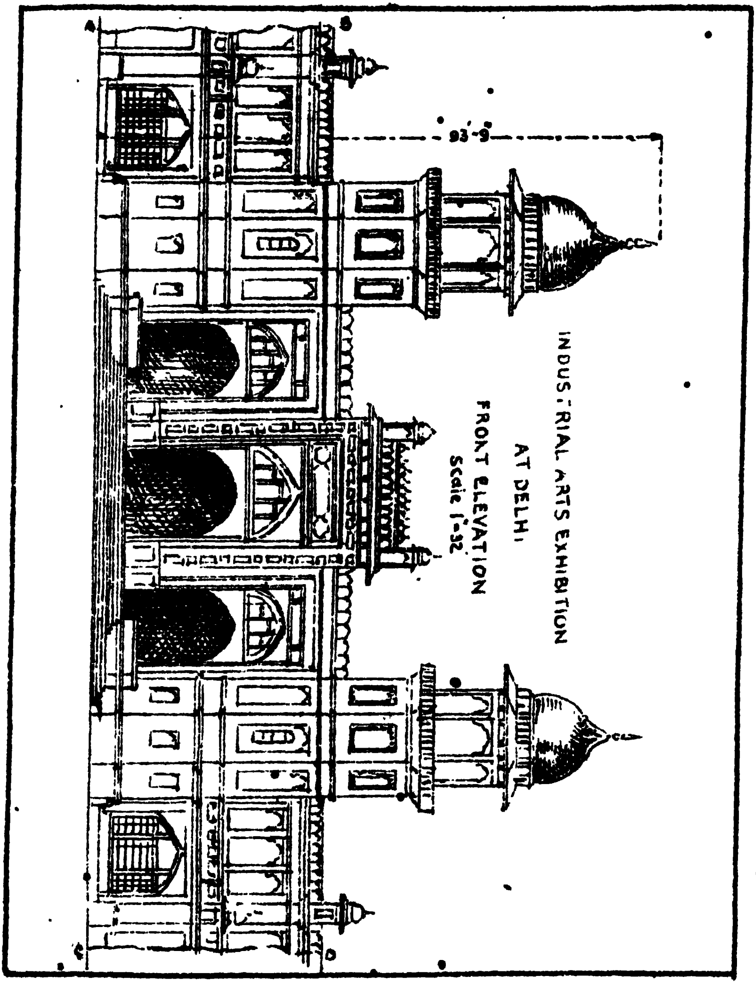

PLAN OF A HALL
LAHORE.
HALL
150 x 60
150-0
60-0
60-0
25 x 16
25x25
25x16



CROSS SECTION OF THE HALL
Scale: 24=1"


CORONATION DURBAR DELHI
PART ELEVATION OF THE FRONT OF EMPHITHEATRE
Scale 12'=1"

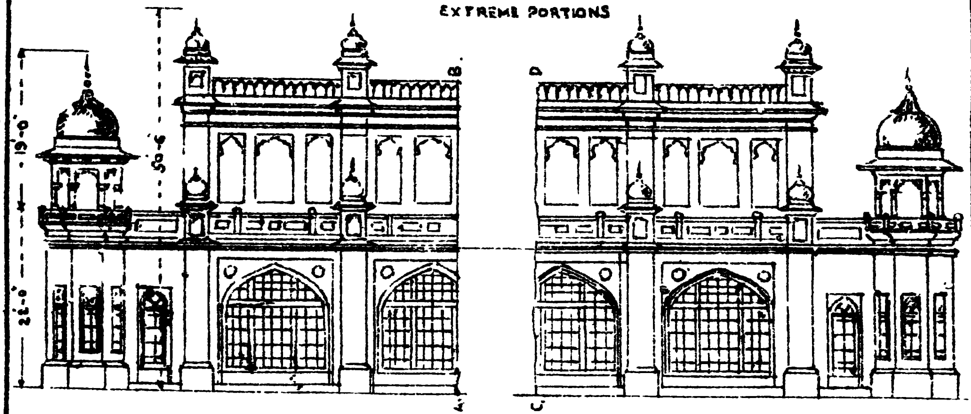

INDUSTRIAL ARTS EXHIBITION COR. DARBAR
DELHI
GROUNDPLAN
Scale, 1"=56'



INDUSTRIAL ARTS EXHIBITION
AT DELHI
FRONT ELEVATION
Scale 1"=32'
93'-9"

INDUSTRIAL ARTS EXHIBITION
AT DELHI

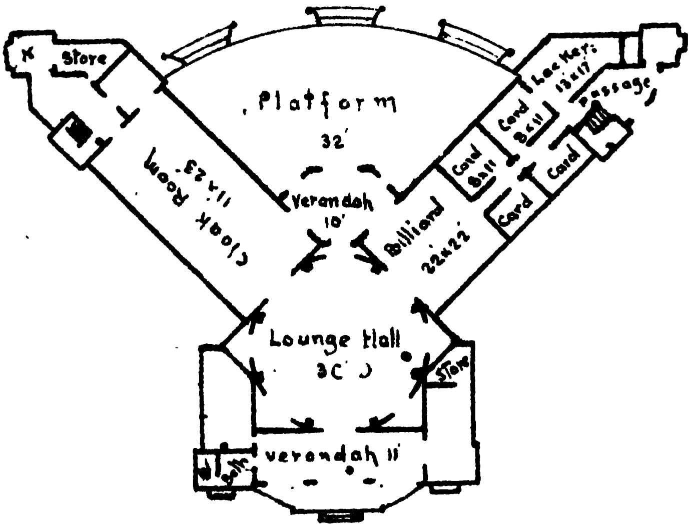
FRONT ELEVATION OF THE
EXTREME PORTIONS



Scale, 24'=1"

DESIGN FOR GENTLEMEN'S CLUB

Scale ... 40' = 1"

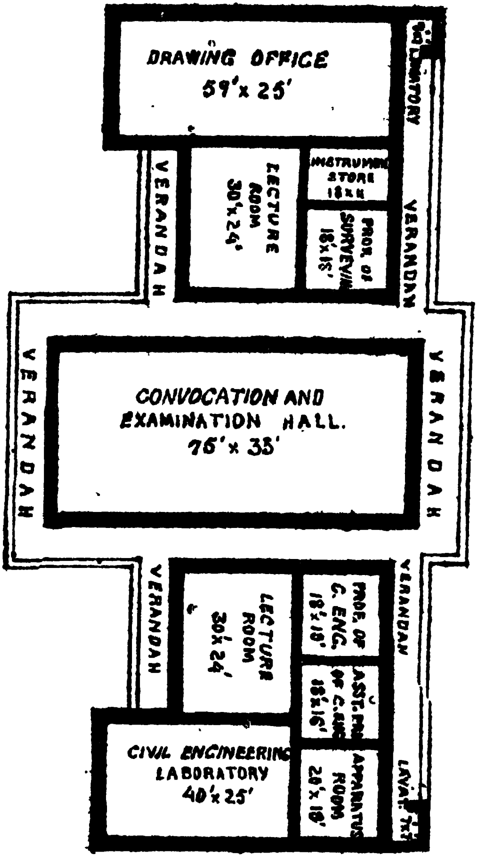


GROUND PLAN

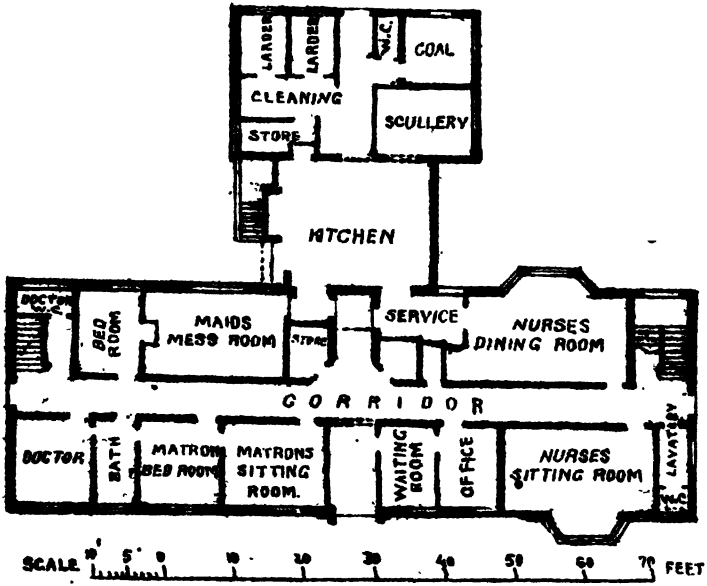
PLAN FOR AN ENGINEERING COLLEGE

CIVIL ENGINEERING & SURVEYING BLOCK

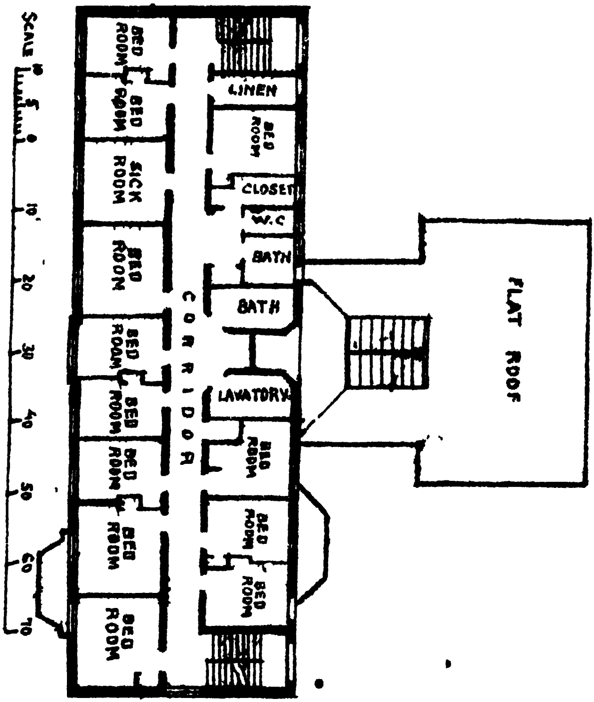
SCALE 1" = 40 FT.



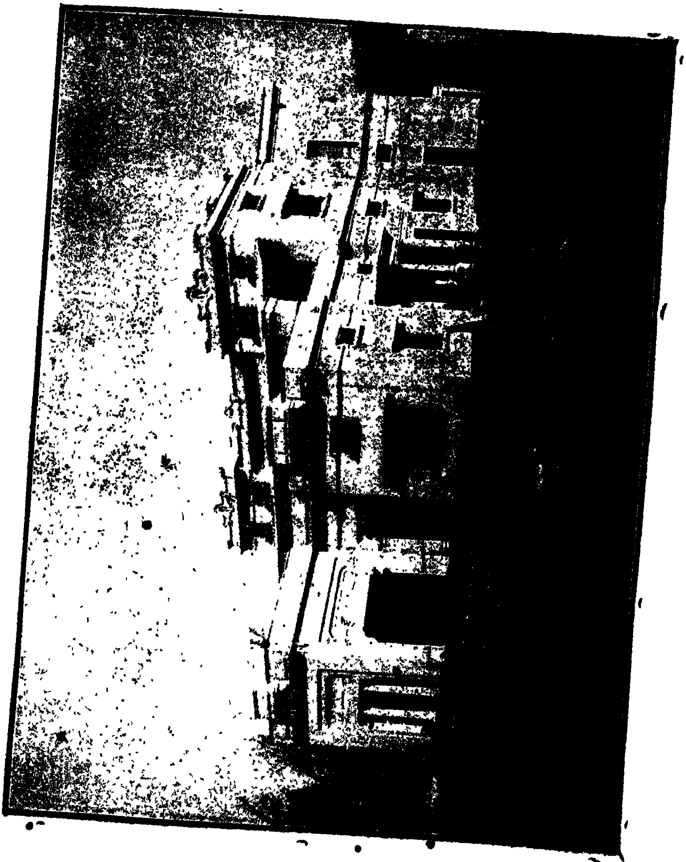
PLAN OF A MATERNITY HOSPITAL
GROUND FLOOR.



PLAN OF A MATERNITY HOSPITAL
FIRST FLOOR

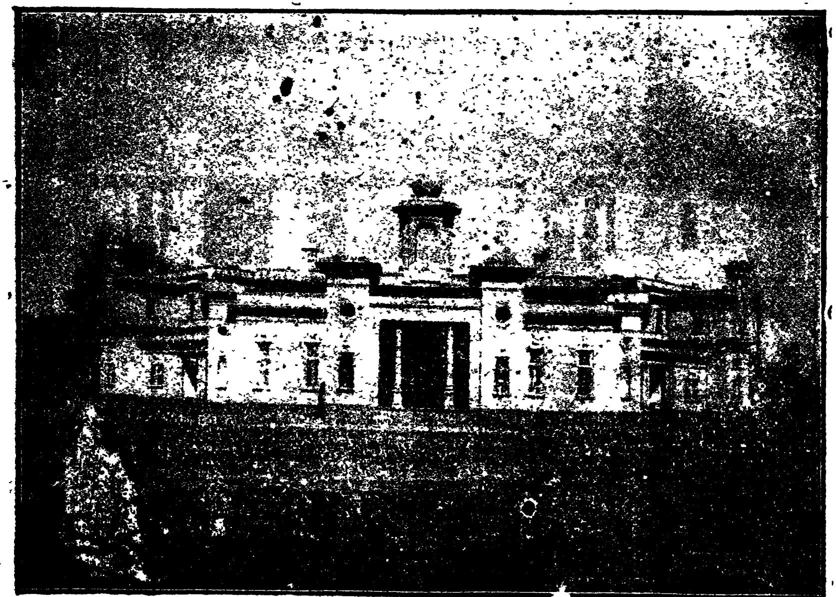


Model Town—Lahore.



Sir Ganga Ram's-Bangalow

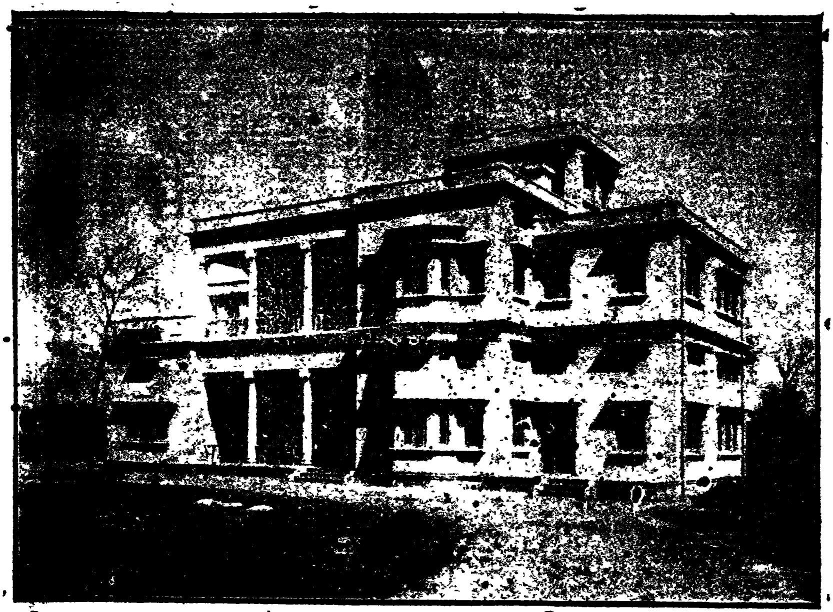
Model Town—Lahore



The Club.—(Front view.)

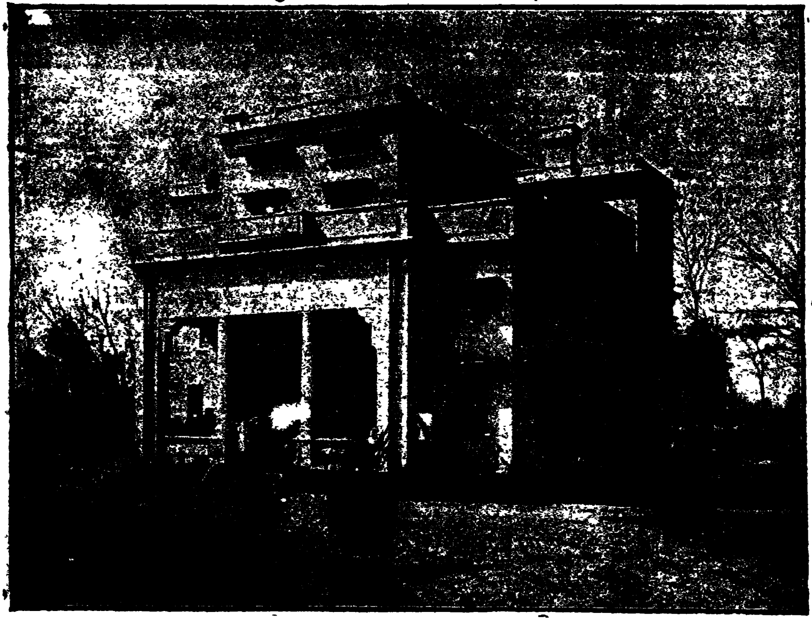
For Plan See Page 541.

Model Town--Lahore.



A Class Bangalow.

Model Town—Lahore.



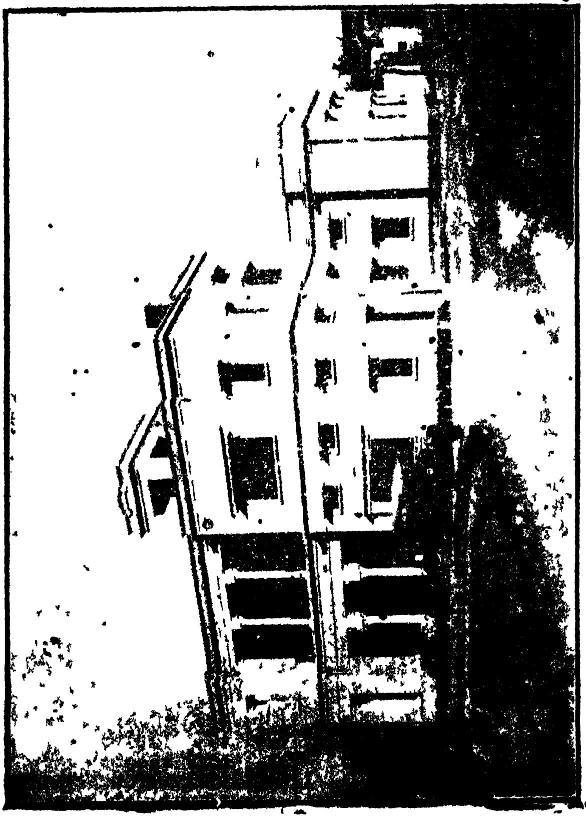
B Class Bangalow.

Model Town—Lahore.



C Class Bangalow.

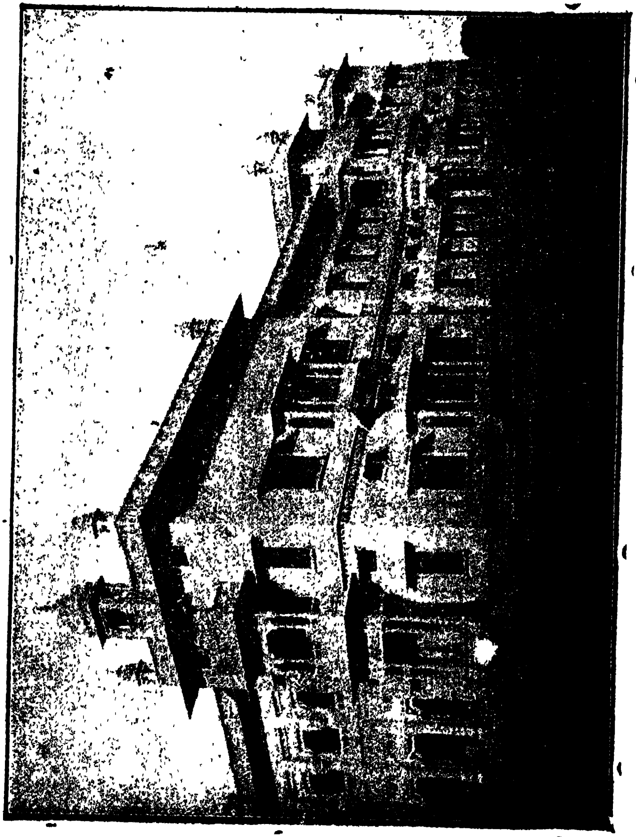
Model Town—Lahore.



Arts College Benares Hindu University



Benares Hindu University

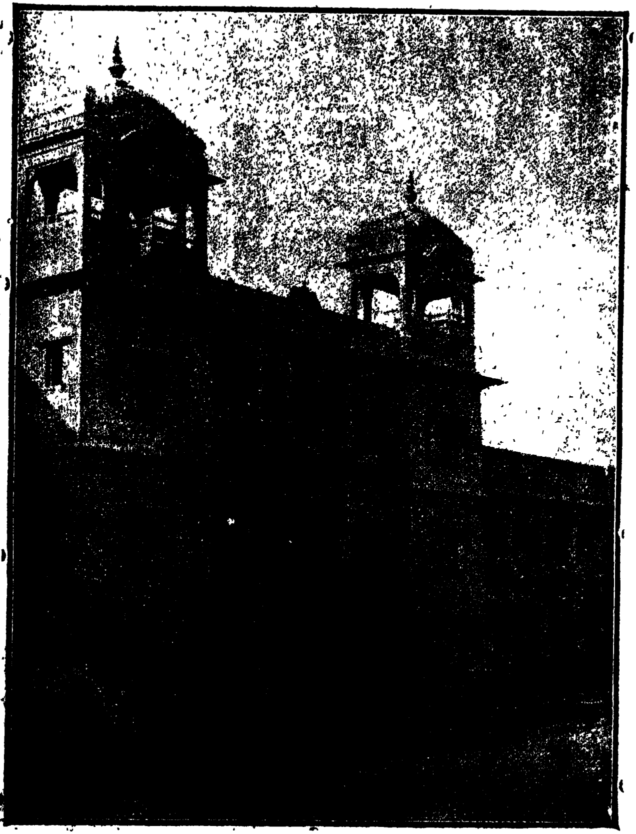


Part Front Elevation
ARTS COLLEGE (BENARES HINDU UNIVERSITY).



Front view of Hostel.

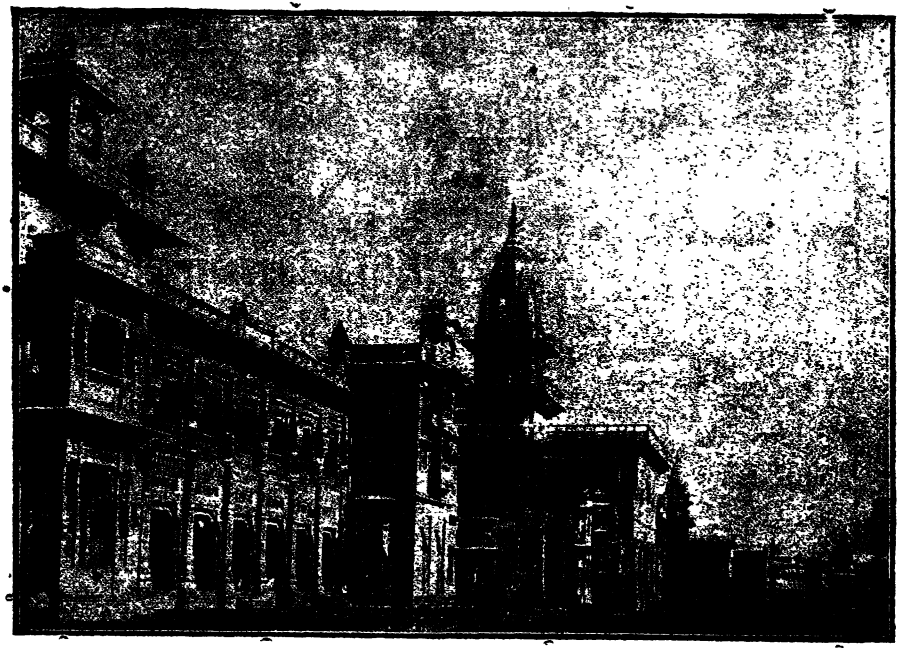
BENARES HINDU UNIVERSITY.



Front view of Hostel.



Front view Chemical Laboratory



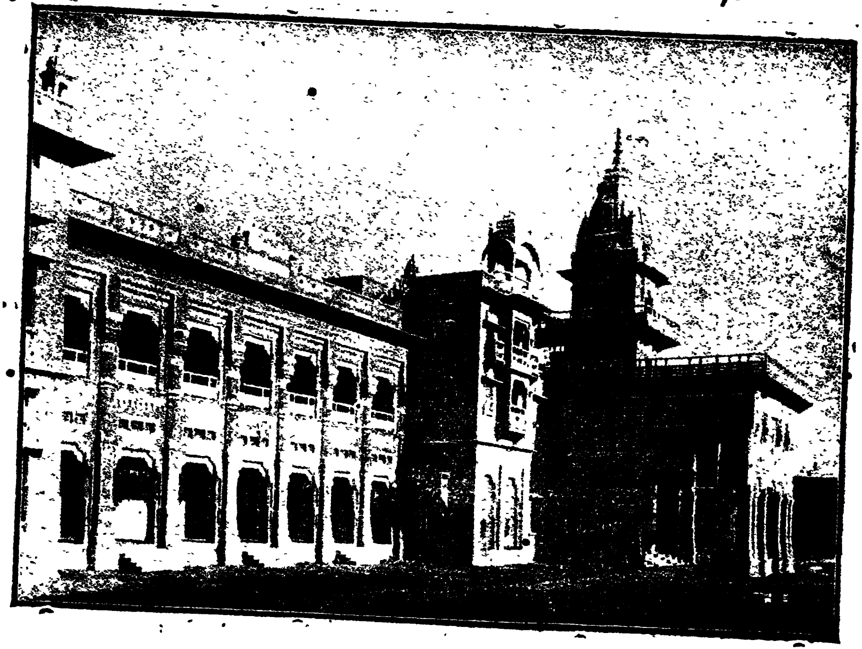
Front view Chemical Laboratory.



Side Elevation Chemical Laboratory.

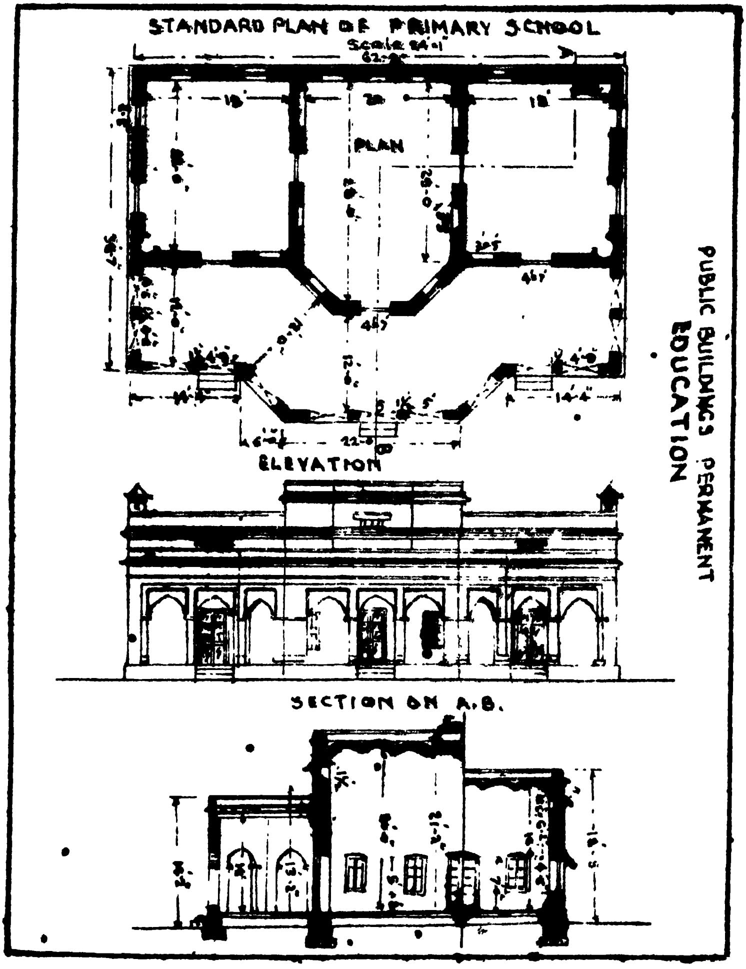


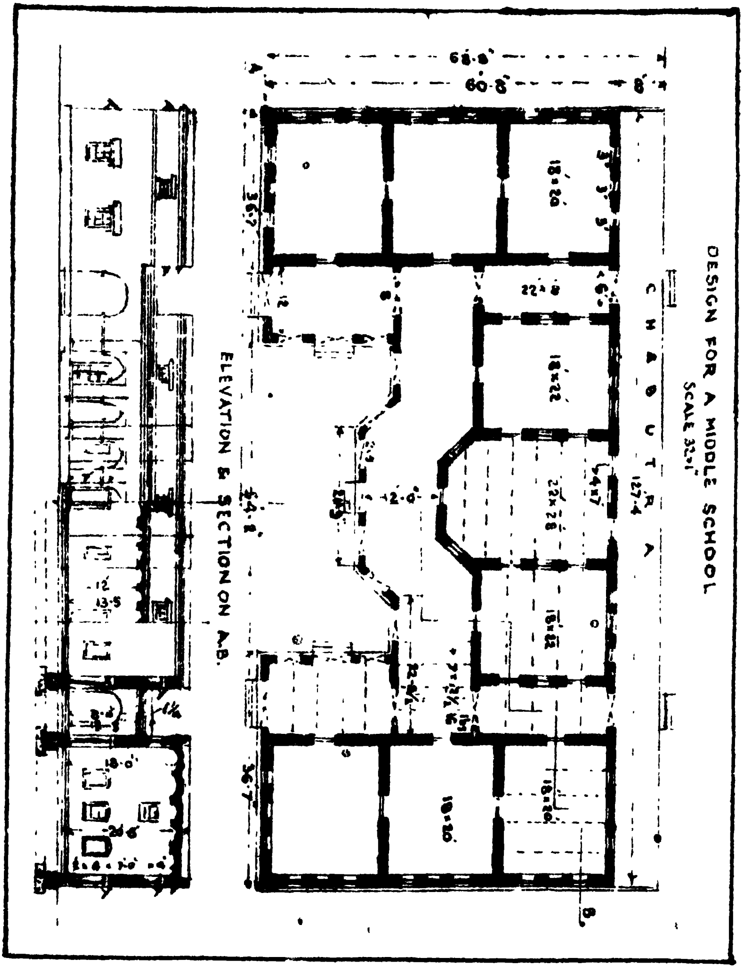
Front view Physics Laboratory.



Front Elevation Physics Laboratory.

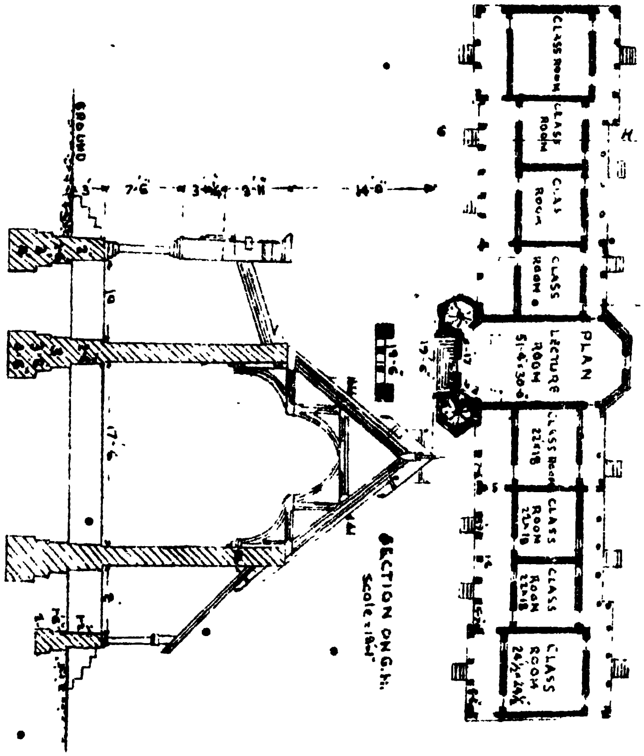


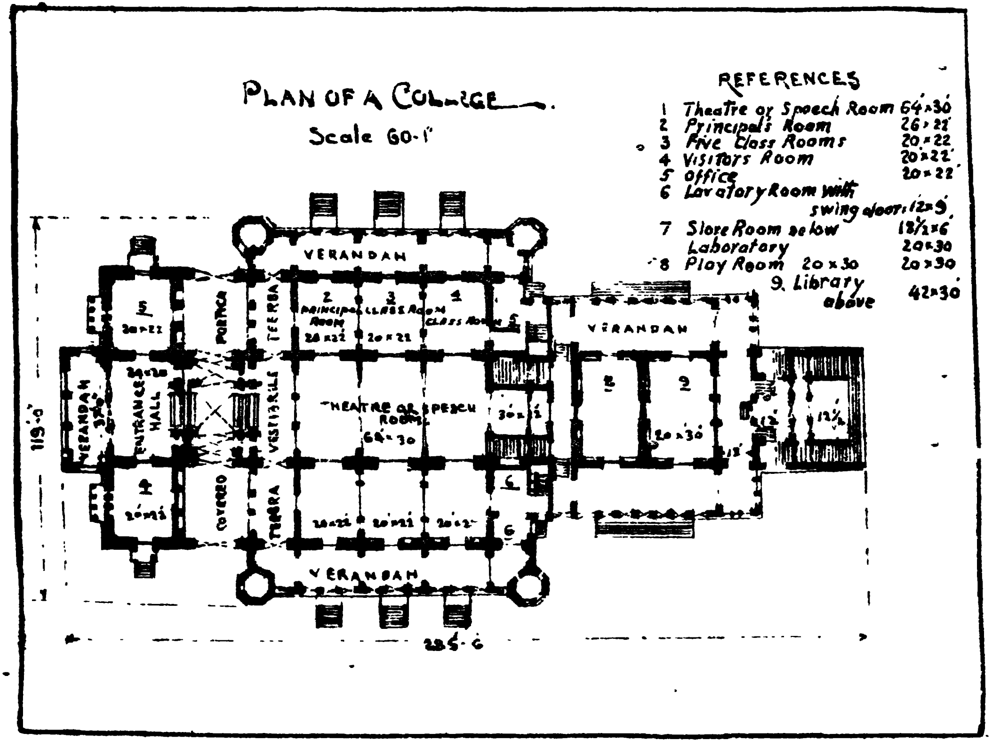

STANDARD PLAN OF PRIMARY SCHOOL
PLAN
ELEVATION
SECTION ON A.B.
PUBLIC BUILDINGS PERMANENT
EDUCATION

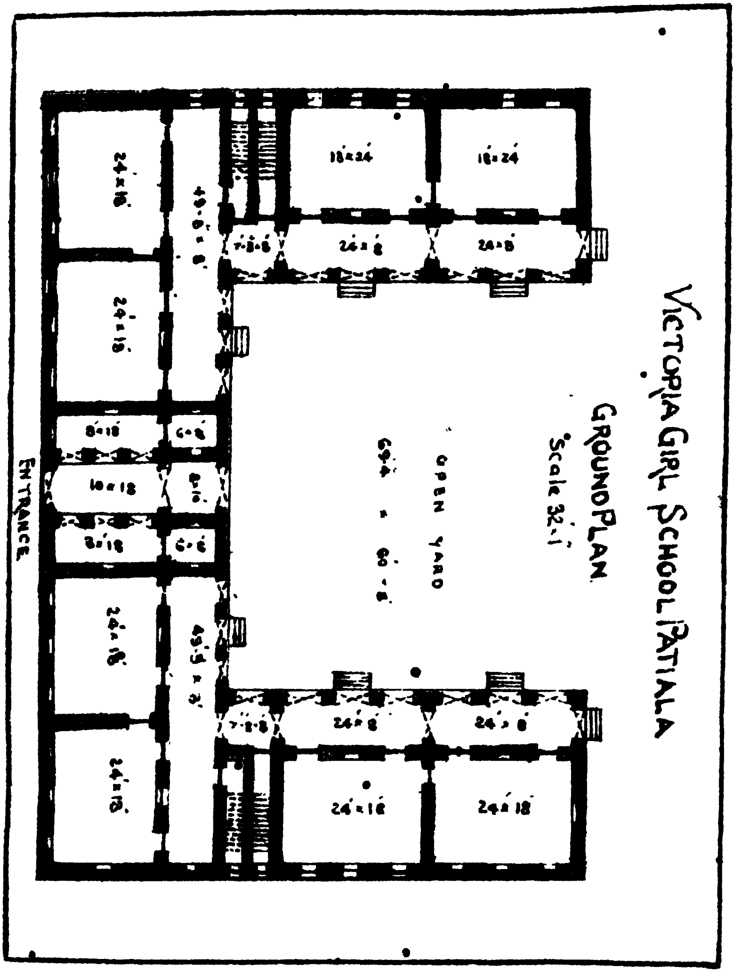

DESIGN FOR A MIDDLE SCHOOL
SCALE 32=1"
CHABUTRA
ELEVATION & SECTION ON A.B.
68·8"
60·8"
8"
18×26
22×8
18×22
22×28
127·4
36·7
24·8
12·0"

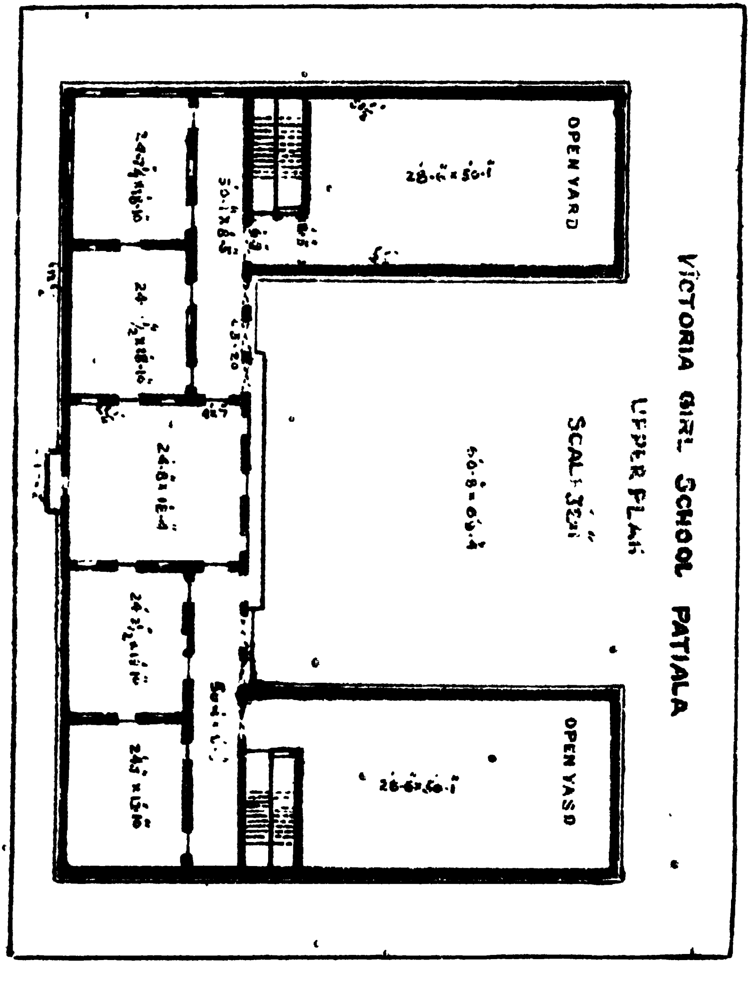
THE SURAT HIGH SCHOOL

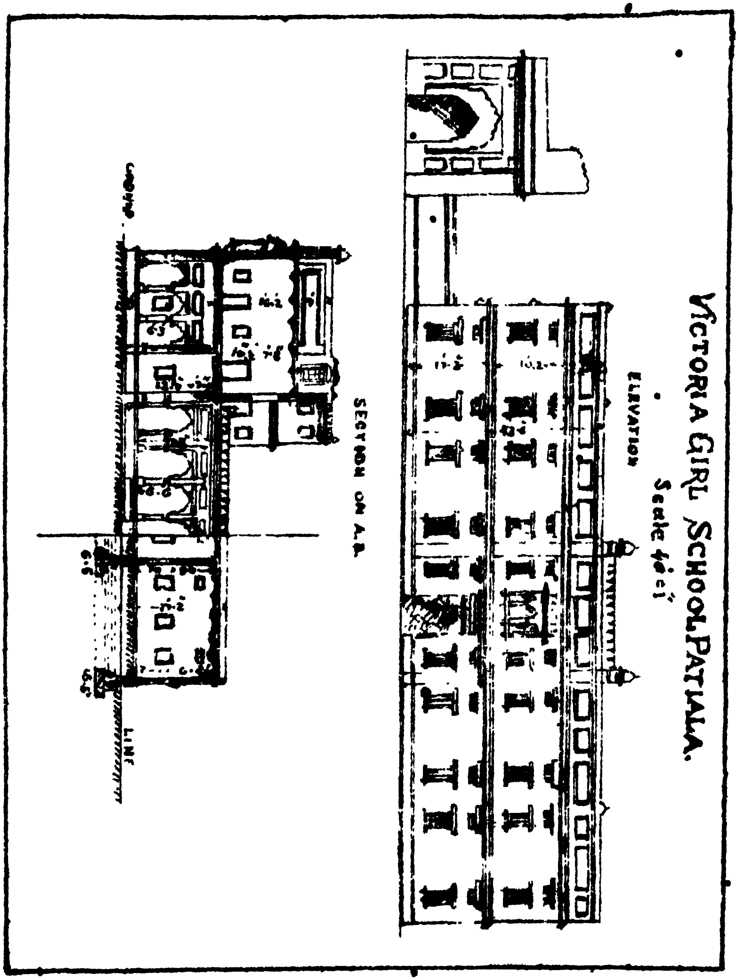
Scale 60': 1"

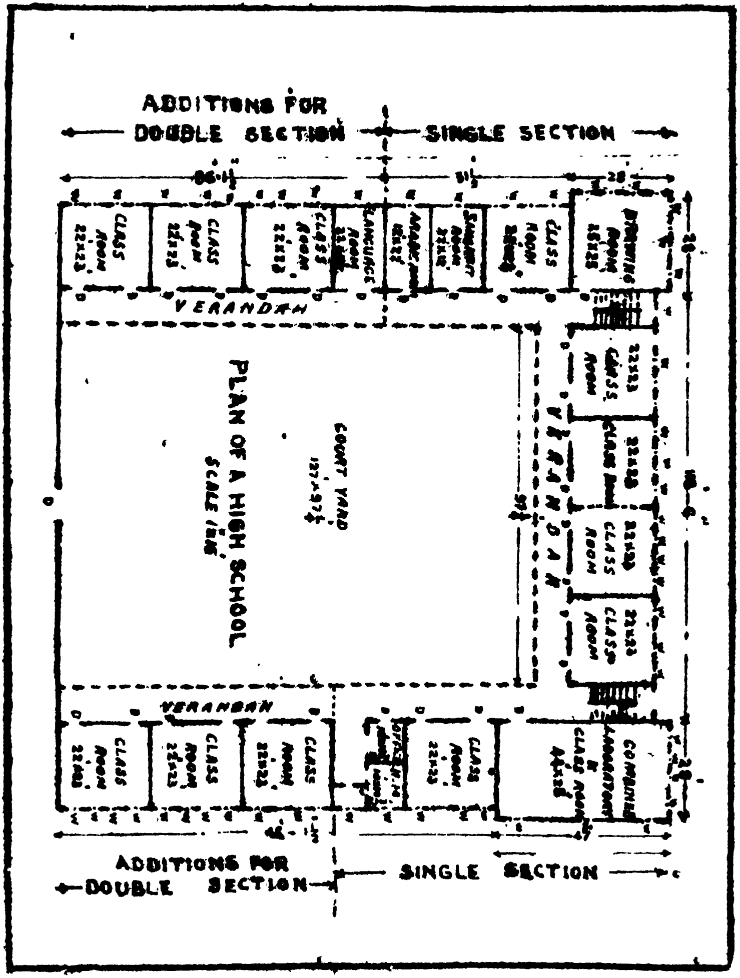


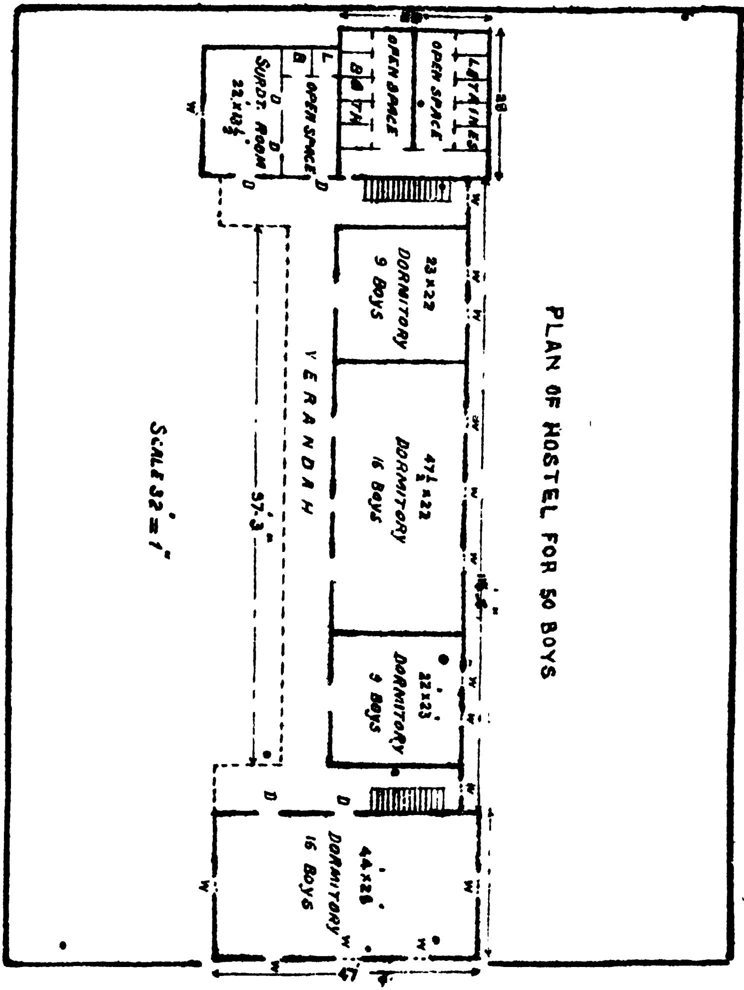

PLAN OF A COLLEGE.
Scale 60-1"
REFERENCES
1 Theatre or Speech Room 64×30
2 Principal's Room 26×22
3 Five Class Rooms 20×22
4 Visitors Room 20×22
5 Office 20×22
6 Lavatory Room with swing doors 12×9
7 Store Room below Laboratory 13½×6 20×30
8 Play Room 20×30 20×30
9. Library above 42×30
VERANDAH
PORTICO
TERRA
PRINCIPAL ROOM
CLASS ROOM
ENTRANCE HALL
VESTIBULE
THEATRE OR SPEECH ROOM 64×30
COVERED
119'-0"
235'-6"


VICTORIA GIRL SCHOOL PATIALA
GROUND PLAN
Scale 32'-1"
OPEN YARD
69'-4" x 60'-8"
ENTRANCE


VICTORIA GIRL SCHOOL PATIALA
UPPER PLAN
OPEN YARD
OPEN YARD

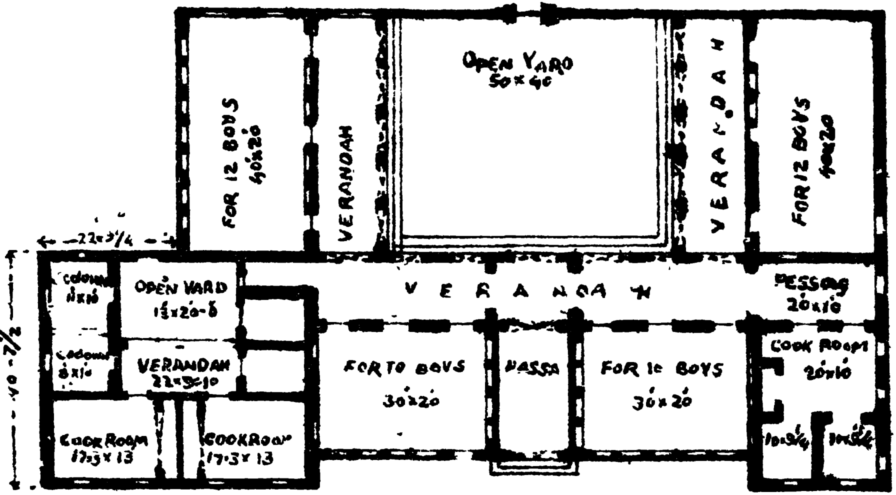

VICTORIA GIRL SCHOOL PATIALA.
ELEVATION
SECTION ON A.B.
LINE


ADDITIONS FOR
DOUBLE SECTION
SINGLE SECTION
CLASS ROOM 22x23
VERANDAH
PLAN OF A HIGH SCHOOL
COURT YARD
VERANDAH
CLASS ROOM
ADDITIONS FOR
DOUBLE SECTION
SINGLE SECTION


PLAN OF HOSTEL FOR 50 BOYS
LATRINES
OPEN SPACE
OPEN SPACE
BATH
OPEN SPACE
SUPDT. ROOM
22x18½
23x22
DORMITORY
9 BOYS
47½x22
DORMITORY
16 BOYS
22x23
DORMITORY
9 BOYS
44x28
DORMITORY
16 BOYS
VERANDAH
57.3
38
47
SCALE 32=1"

PLAN OF A BOARDING HOUSE FOR 44 BOYS

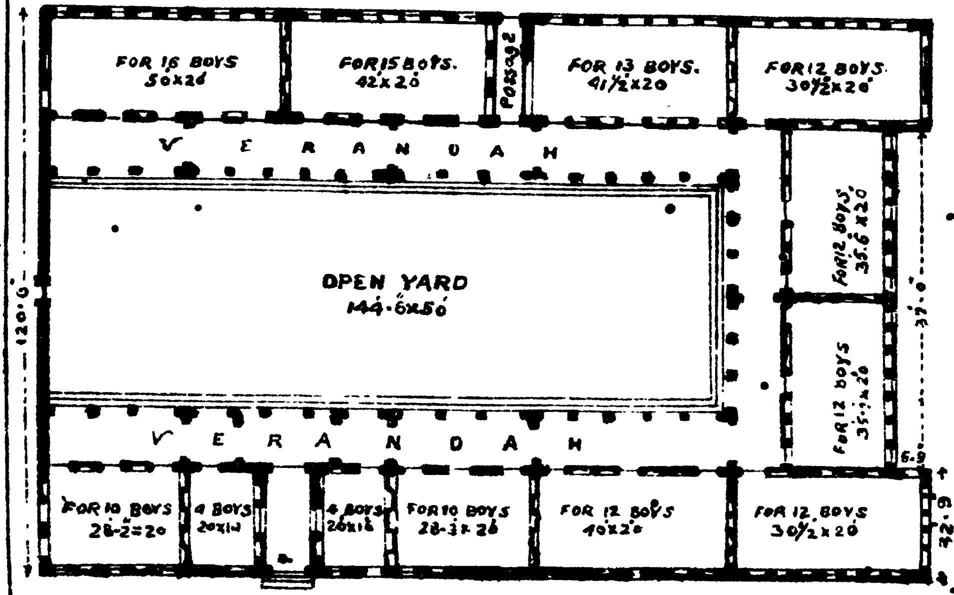
GROUND PLAN.

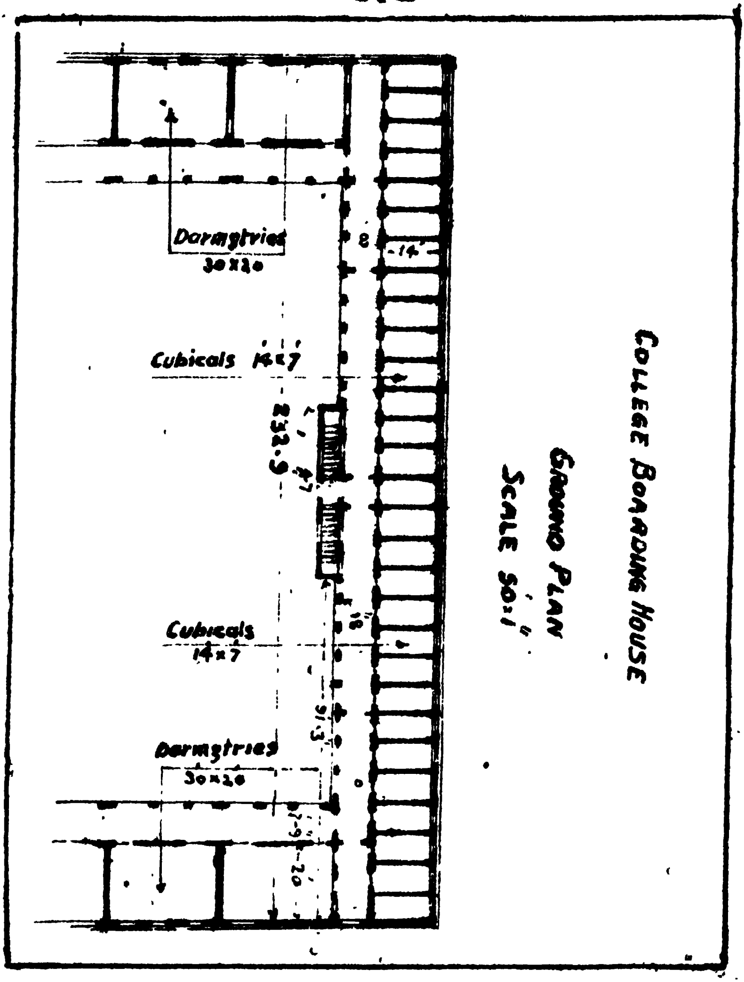


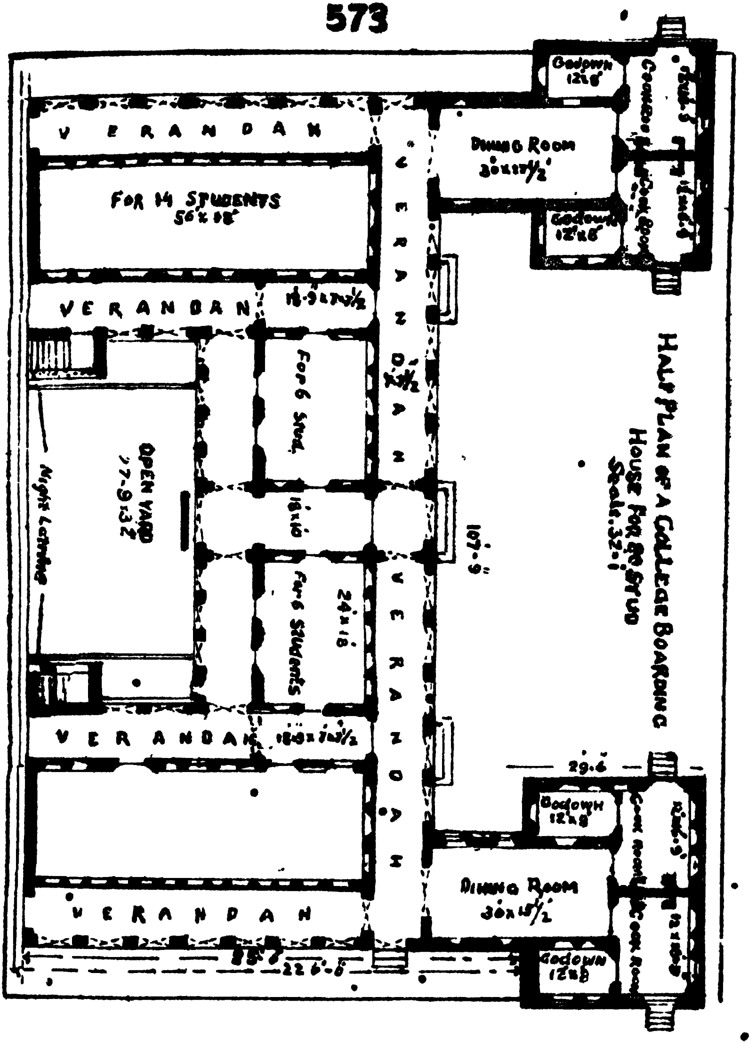
Scale. 32′=1″

PLAN OF A BOARDING HOUSE FOR 132 STUDENTS

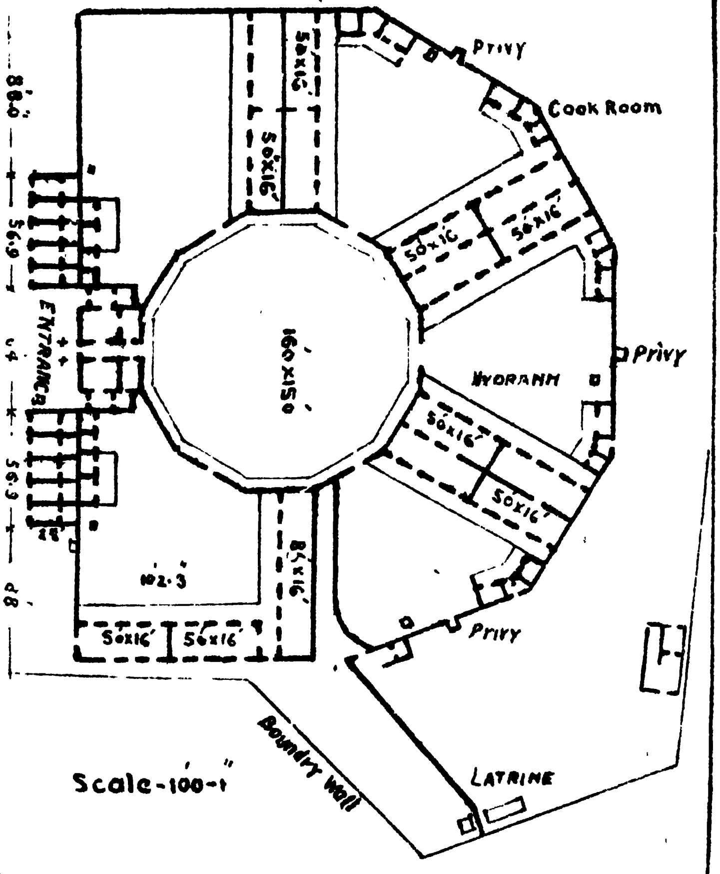
SCALE = 40 = 1



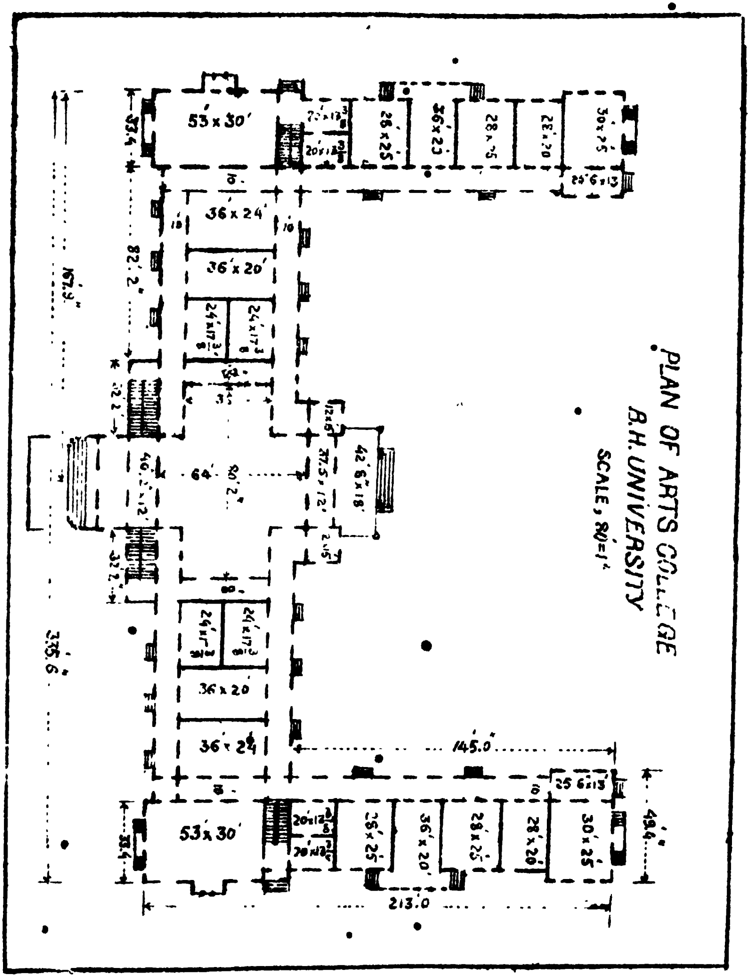

COLLEGE BOARDING HOUSE
GROUND PLAN
SCALE 50':1"
Dormitries
30x20
Cubicals 14x7
232.9
Cubicals
14x7
91.3
Dormitries
30x20

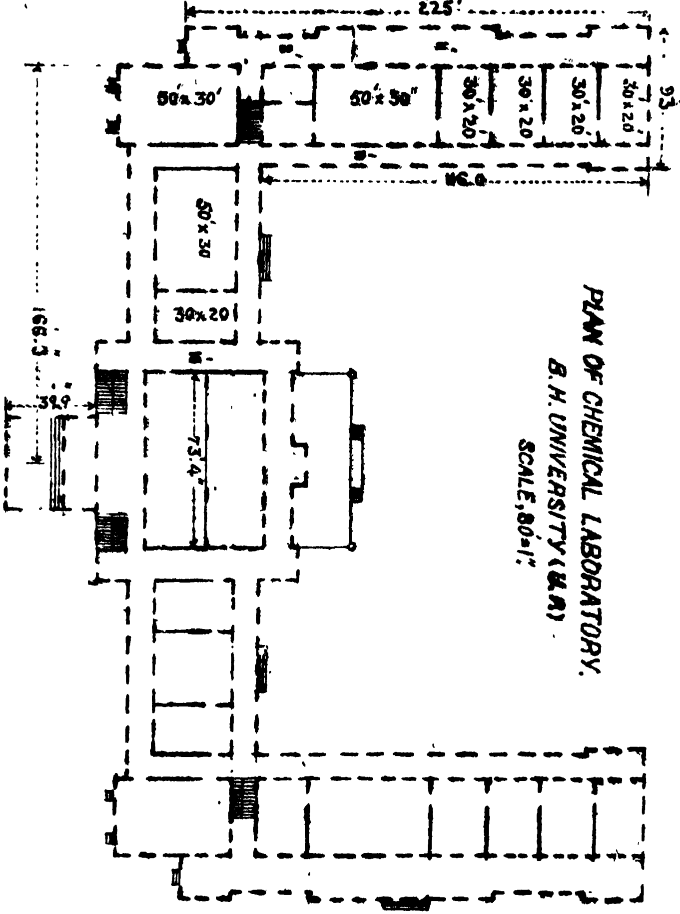

HALF PLAN OF A COLLEGE BOARDING HOUSE FOR 80 STUD
Scale 32'=1"
VERANDAH
FOR 14 STUDENTS
56'x 18'
VERANDAH
For 6 Stud.
18x10
For 6 Students
24x18
OPEN YARD
Night Latrine
VERANDAH
VERANDAH
VERANDAH
DINING ROOM
DINING ROOM
Godown
Godown
Godown
Godown
Cook Room
Cook Room
29.6
107-9"
226'-6"

A COLLEGE BOARDING HOUSE

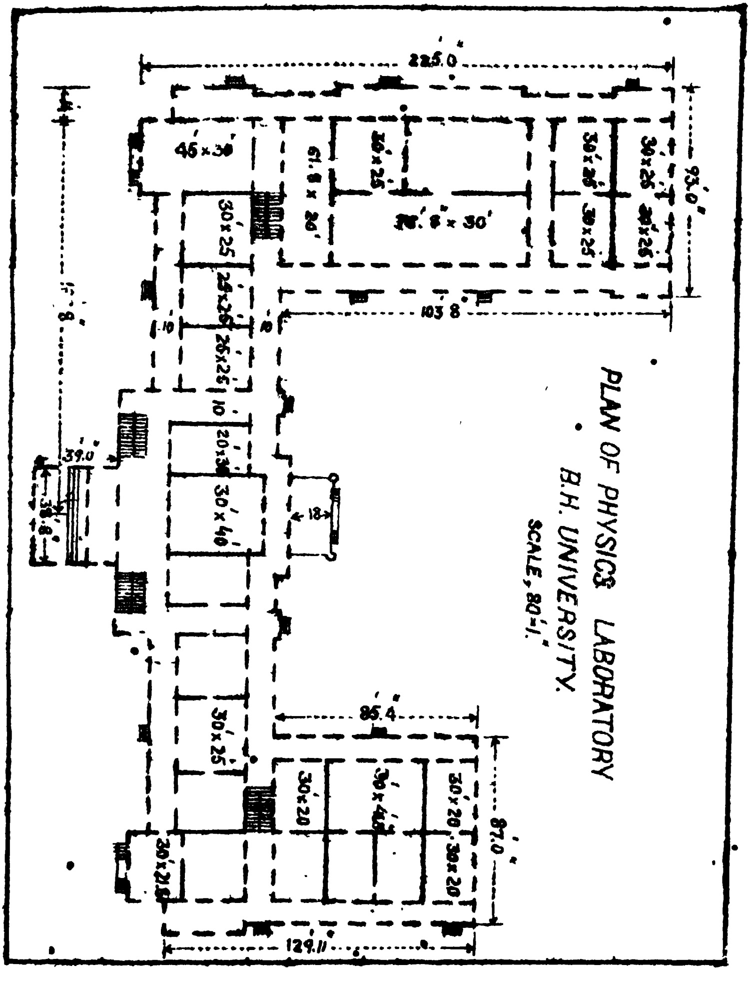


Scale-100-1"

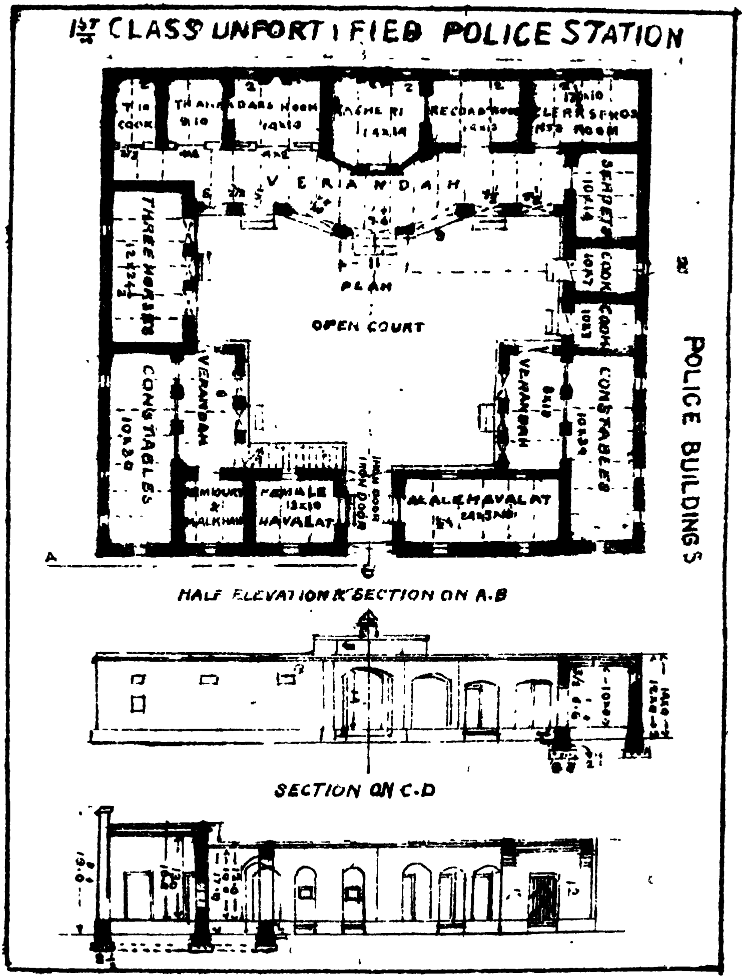

PLAN OF ARTS COLLEGE
B.H. UNIVERSITY
SCALE, 80'=1"



PLAN OF CHEMICAL LABORATORY.
B. H. UNIVERSITY (U.P.)
SCALE, 80'=1".



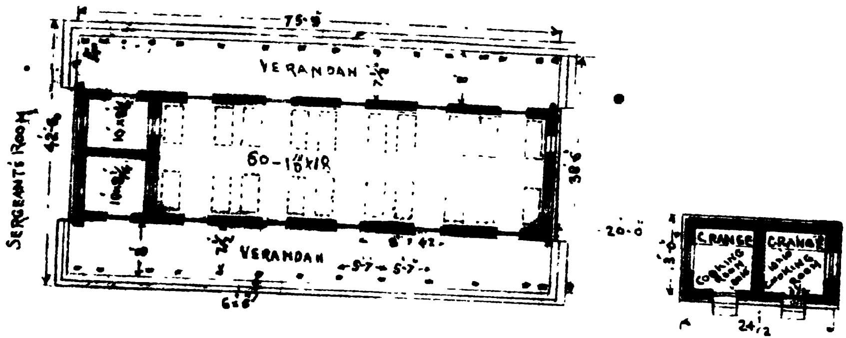
PLAN OF PHYSICS LABORATORY
B.H. UNIVERSITY.
SCALE, 80'=1".


1ST CLASS UNFORTIFIED POLICE STATION
POLICE BUILDINGS
COOK
THANADARS ROOM
KACHERI
RECORD ROOM
VERANDAH
THREE HORSES
PLAN
OPEN COURT
COOK
CONSTABLES
VERANDAH
FEMALE HAVALAT
MALE HAVALAT
IRON DOOR
HALF ELEVATION & SECTION ON A.B
SECTION ON C.D

PUBLIC BUILDINGS PERMANENT

POLICE BARRACKS FOR 20 MEN.

Scale, 50' = 1"

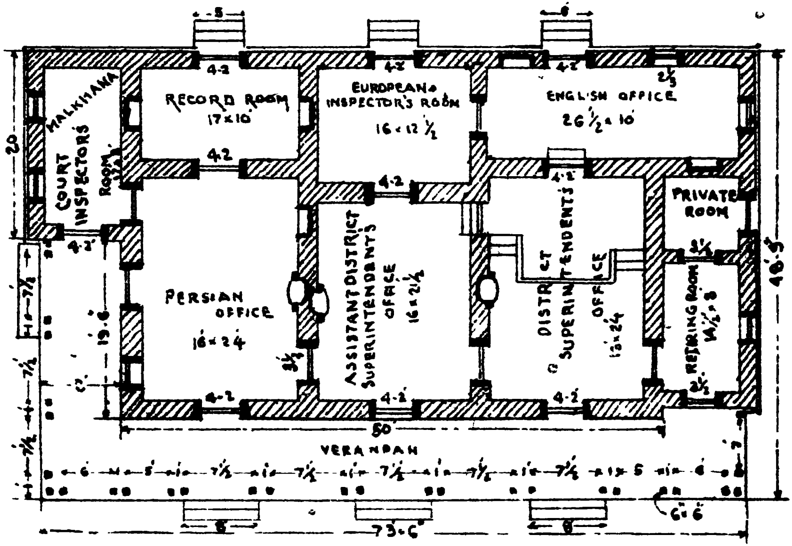


NOTE.—Floor of all living rooms to be not less than 2 feet above ground. Verandah floor to have 3 inches outward slope, all doors to be ⅓rd glazed and ⅔rd panelled, and windows exposed to sun or rain to be provided with sun shades.

Main ward and sergeant's rooms to be provided with ventilators with sun-shades, cooking rooms to be provided with battened doors and ½ glazed windows with sun-shades. Arches, jambs of doors, windows, ventilators, and parapets to the lower course of the cornice are to be built in Pucca masonry.

FIRST CLASS POLICE OFFICE

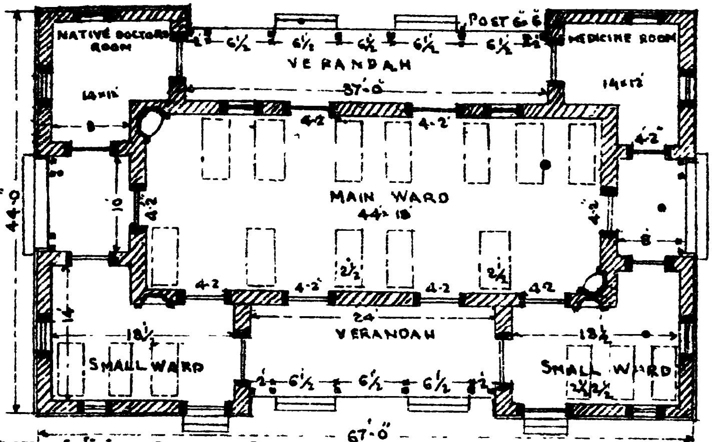
Scale 20' = 1"



NOTE—Arches, jambs of doors, windows, ventilators, and parapets to the lower course of the cornice are to be built in Pucca masonry.

POLICE HOSPITAL FOR 18 MEN

Scale, 20' = 1"



NOTE —

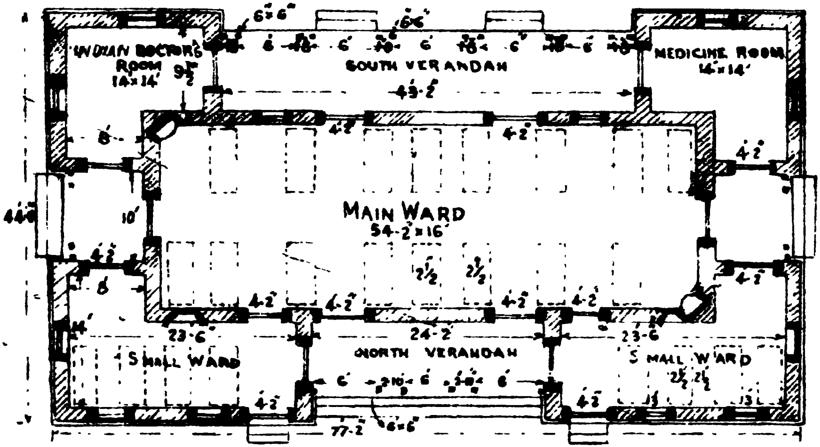
Floors of living Rooms to be not less than 2' above ground Verandah floor to have 3" outward slope

All doors to be ⅓ glazed and ⅔ panelled, and not less than 6'-6" × 3'-6" between Chowkats, Windows exposed to Sun or rain to be provided with Sunshades. All living Rooms to be provided with Ventilators with Sunshades. Arches, Jambs of Doors, Windows Ventilators and Parapets to the lower Coarse of Cornice, to be built in Pucca Masonry. Deep black colour in the Plan show Pucca Masonry.

Space to be provided per Man in the Plains 60 square feet, and 800 cubic feet and in the Hills, 45 square feet. and 600 cubic feet.

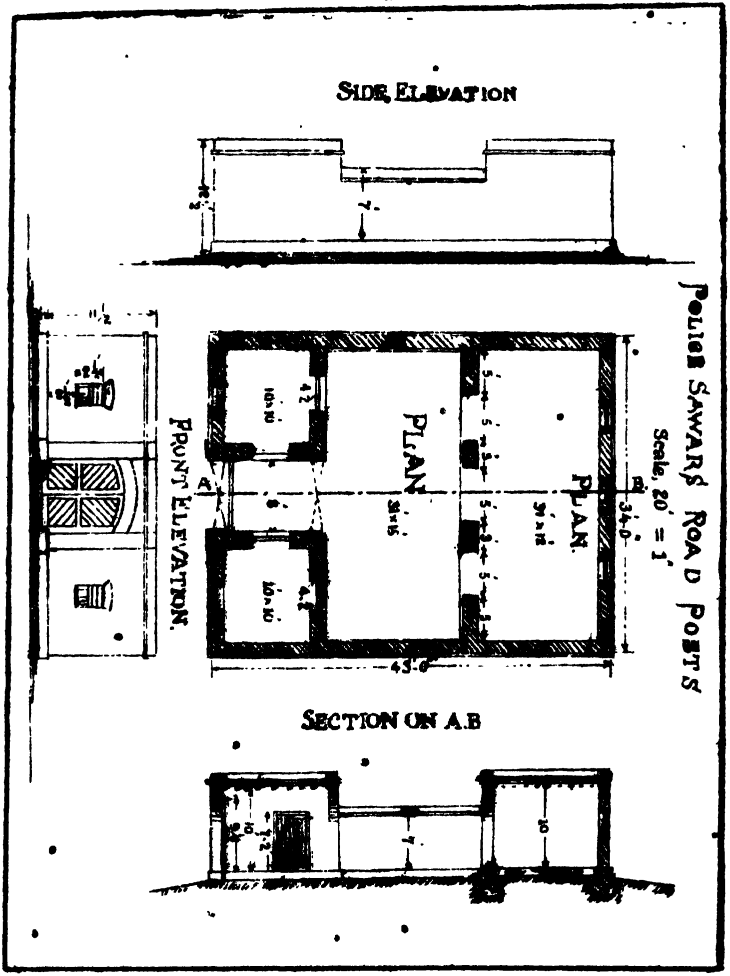
Police Hospital for 24 Men

Scale 20'=1"

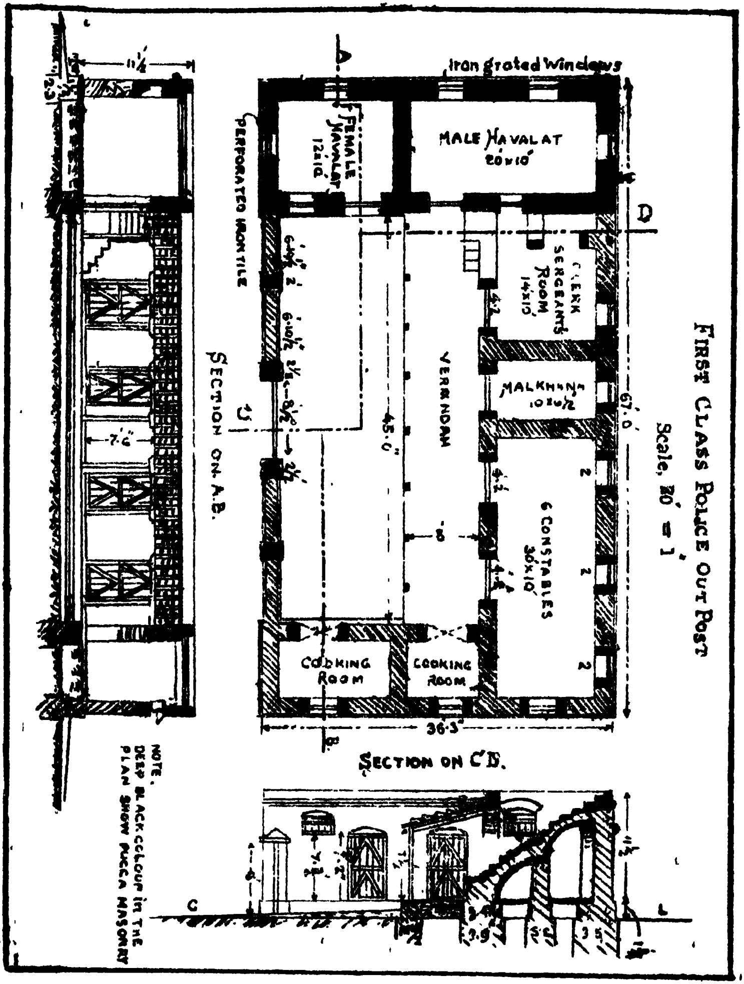


Note—Floor of all living rooms to be not less than 2 feet above ground, Verandah floor to have 3 inches outward slope, all doors to be $\frac{1}{3}$rd glazed and $\frac{2}{3}$rd panelled, and windows exposed to sun or rain to be provided with sun shades.

Main ward and sergeant's rooms to be provided with ventilators with sun-shades, cooking rooms to be provided with battened doors and $\frac{1}{2}$ glazed windows with sun-shades. Arches, jambs of doors, windows, ventilators, and parapets to the lower course of the cornice are to be built in Pucca masonry.

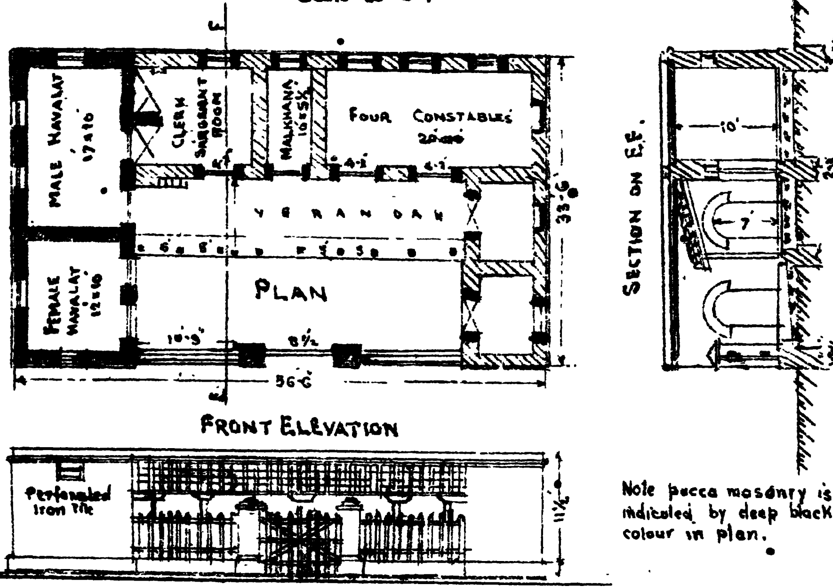


SIDE ELEVATION
FRONT ELEVATION
PLAN
PLAN
POLICE SAWARS ROAD POSTS
Scale, 20' = 1"
34-0
45-0
SECTION ON A.B

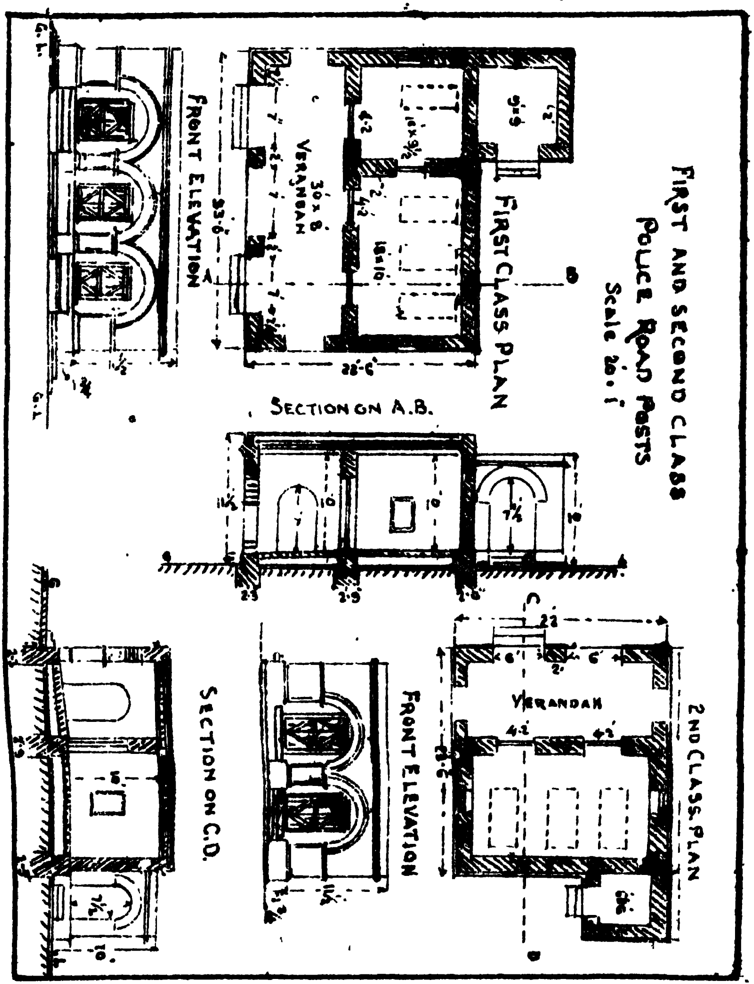

FIRST CLASS POLICE OUT POST
Scale, 20' = 1"
Iron grated Windows
FEMALE HAVALAT 12x10'
MALE HAVALAT 20x10'
PERFORATED IRON TILE
CLERK SERGEANTS ROOM 14x10'
MALKHANA
VERANDAH
6 CONSTABLES 30x10'
COOKING ROOM
COOKING ROOM
67.0
36.3
45.0
SECTION ON A.B.
SECTION ON C'D.
NOTE.
DEEP BLACK COLOUR IN THE PLAN SHOW PUCCA MASONRY

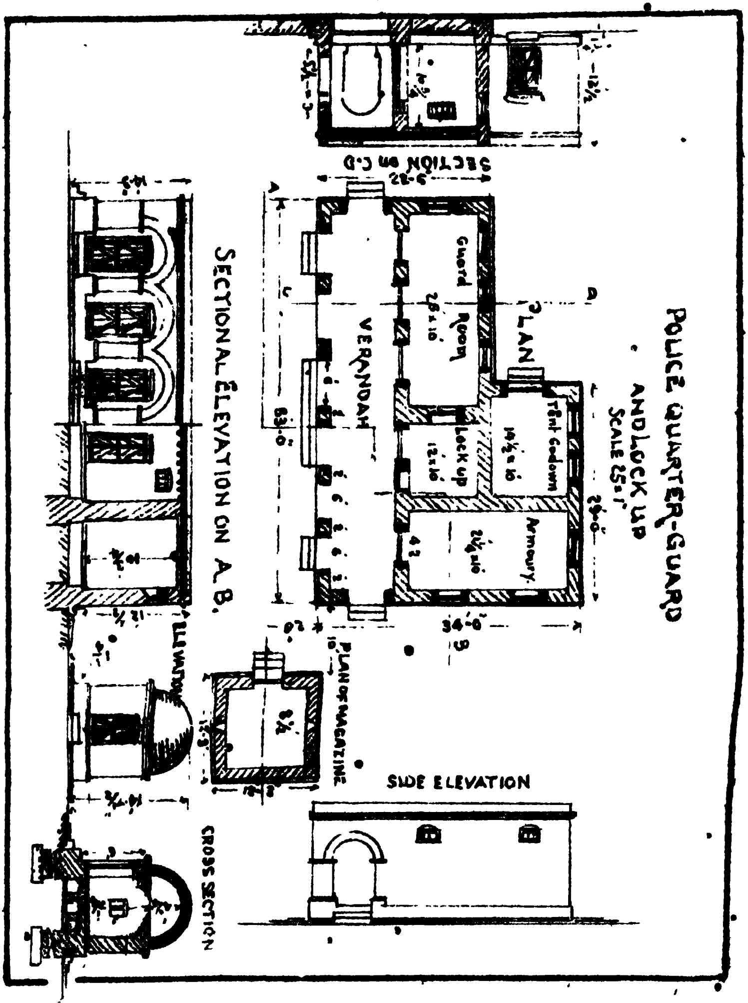
SECOND CLASS POLICE OUT POSTS

Scale 20' = 1"

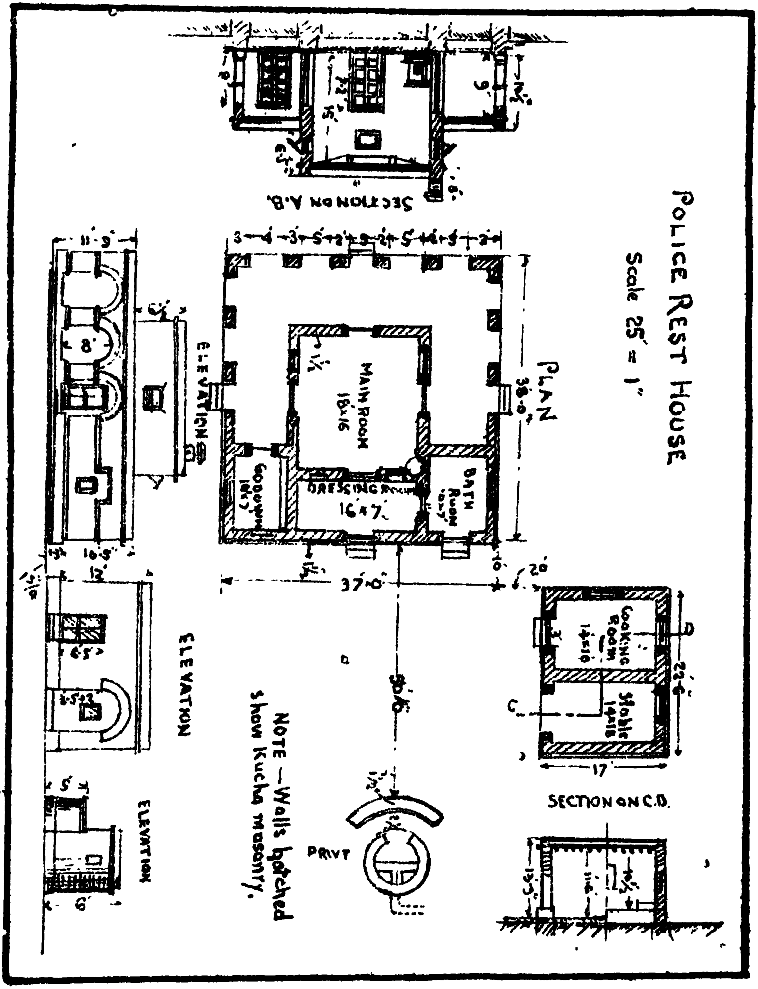


Note pucca masonry is indicated by deep black colour in plan.

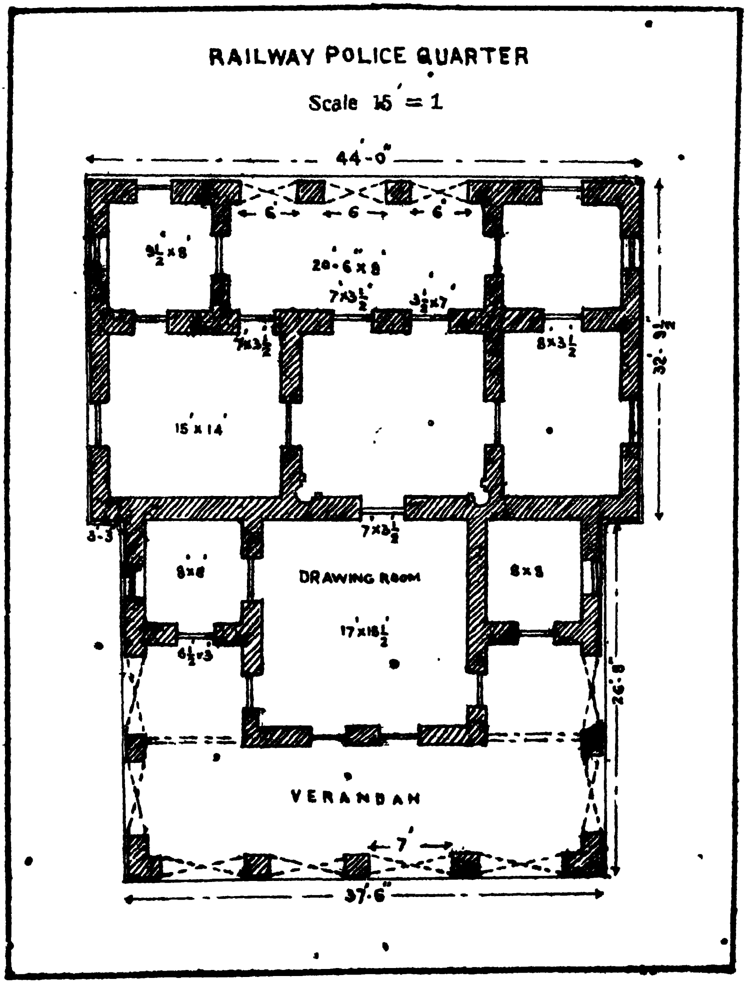

FIRST AND SECOND CLASS
POLICE ROAD POSTS
Scale 20 = 1"
FIRST CLASS PLAN
FRONT ELEVATION
SECTION ON A.B.
2ND CLASS PLAN
FRONT ELEVATION
SECTION ON C.D.
VERANDAH

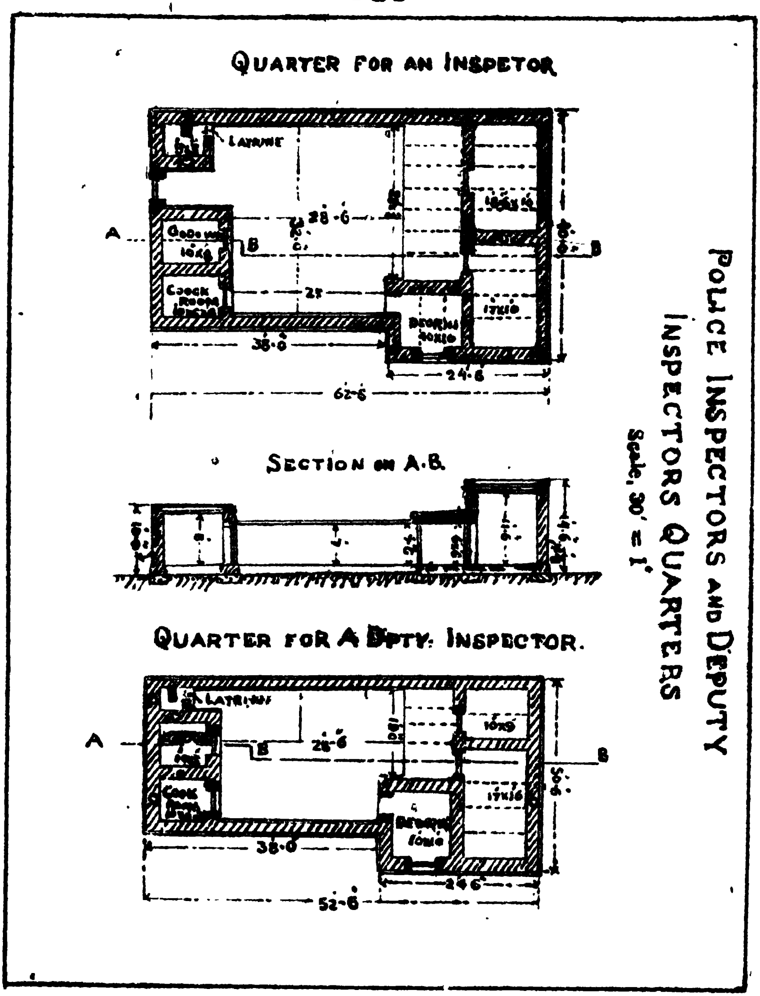


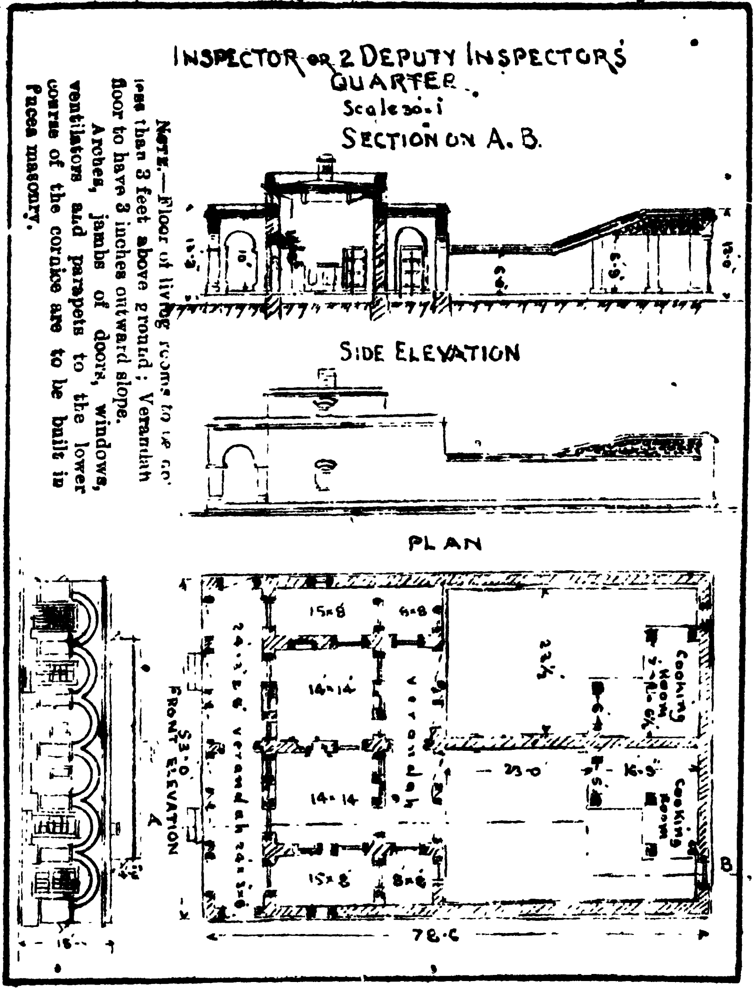
POLICE QUARTER-GUARD AND LOCK UP
SCALE 25=1"
PLAN
Guard Room
VERANDAH
Tent Godown
Lock up
Armoury
SECTION on C.D
SECTIONAL ELEVATION ON A.B.
ELEVATION
PLAN OF MAGAZINE
SIDE ELEVATION
CROSS SECTION



POLICE REST HOUSE
Scale 25' = 1"
PLAN
MAIN ROOM 16x16
DRESSING ROOM 16x7
BATH ROOM
COOKING ROOM
Stable
SECTION ON A.B.
SECTION ON C.D.
ELEVATION
ELEVATION
ELEVATION
PRIVY
NOTE — Walls hatched show kucha masonry.
37'-0"
38'-0"


RAILWAY POLICE QUARTER
Scale 16' = 1
44'-0"
6'
6'
6'
9½' x 8'
20'-6" x 8'
7'x3½'
3½'x7'
7'x3½'
8'x3½'
15' x 14'
32'-9"
8-3
7'x3½'
8'x8'
DRAWING ROOM
17'x18½'
8'x8'
6½'x3'
26'-8"
VERANDAH
7'
37'-6"


QUARTER FOR AN INSPETOR
LATRINE
28·6
Godown
Cook Room
28
38·0
24·6
62·6
Bedroom
17x16
A
B
SECTION ON A·B
QUARTER FOR A DPTY. INSPECTOR.
LATRINE
28·6
16x9
17x16
Cook Room
38·0
24·6
52·6
30·6
POLICE INSPECTORS AND DEPUTY INSPECTORS QUARTERS
Scale, 30' = 1"

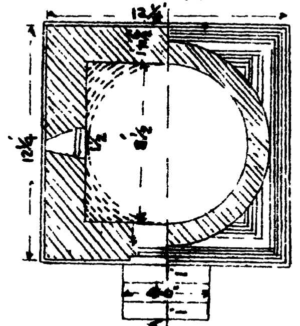

INSPECTOR OR 2 DEPUTY INSPECTORS QUARTER.
Scale 30=1
SECTION ON A. B.
SIDE ELEVATION
PLAN
FRONT ELEVATION
NOTE.—Floor of living rooms to be not less than 3 feet above ground; Verandah floor to have 3 inches outward slope.
Arches, jambs of doors, windows, ventilators and parapets to the lower course of the cornice are to be built in Pucca masonry.
15×8
14×14
Cooking Room
Verandah
78.6
53.0
A
B

MAGAZINE

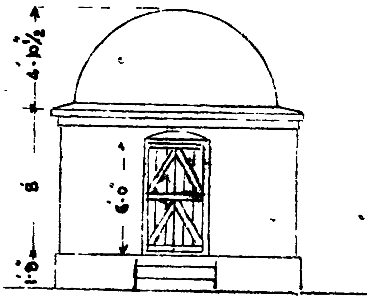
Scale 10′ = 1″

NOTE — Floor to be not less than 2 feet above ground to prevent damp getting into arches and covered with thick coating of asphalt. Ballened door, with copper fastenings, whole Pucca masonry.

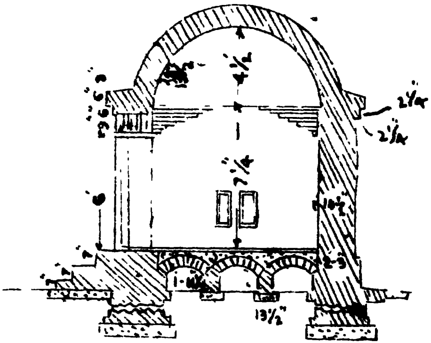
PLAN

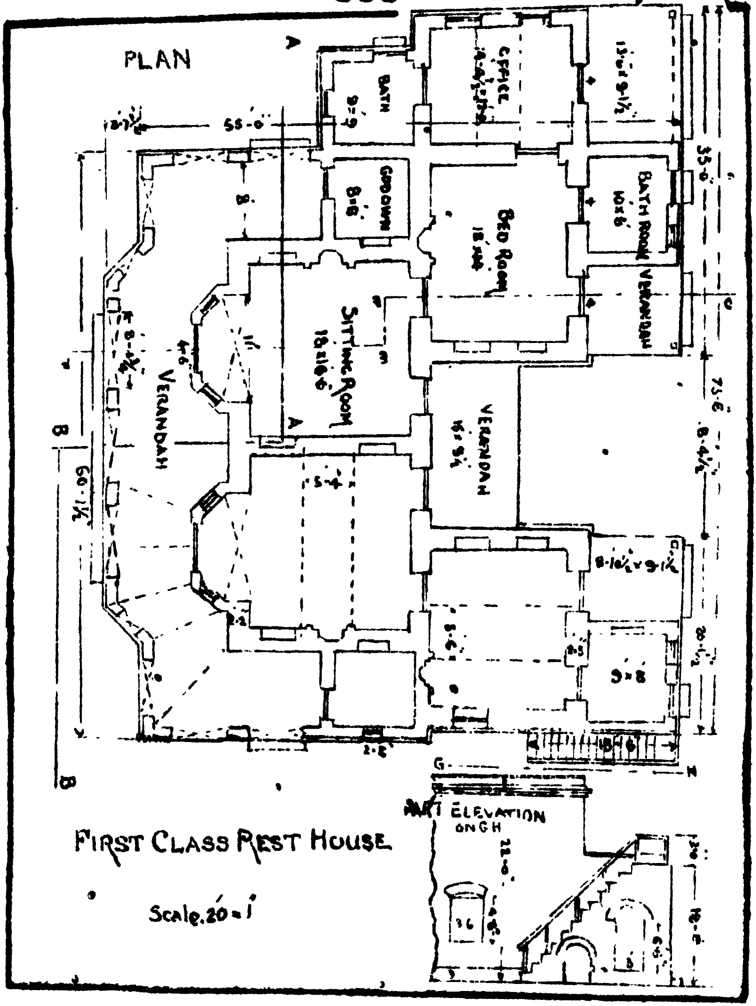


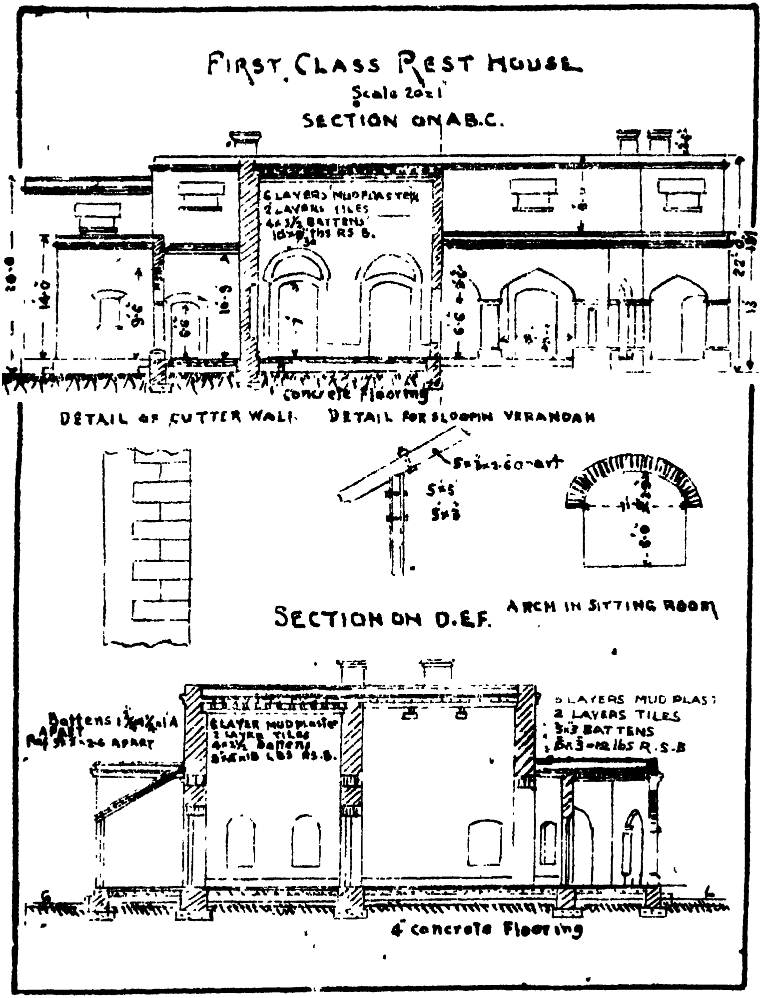
FRONT ELEVATION

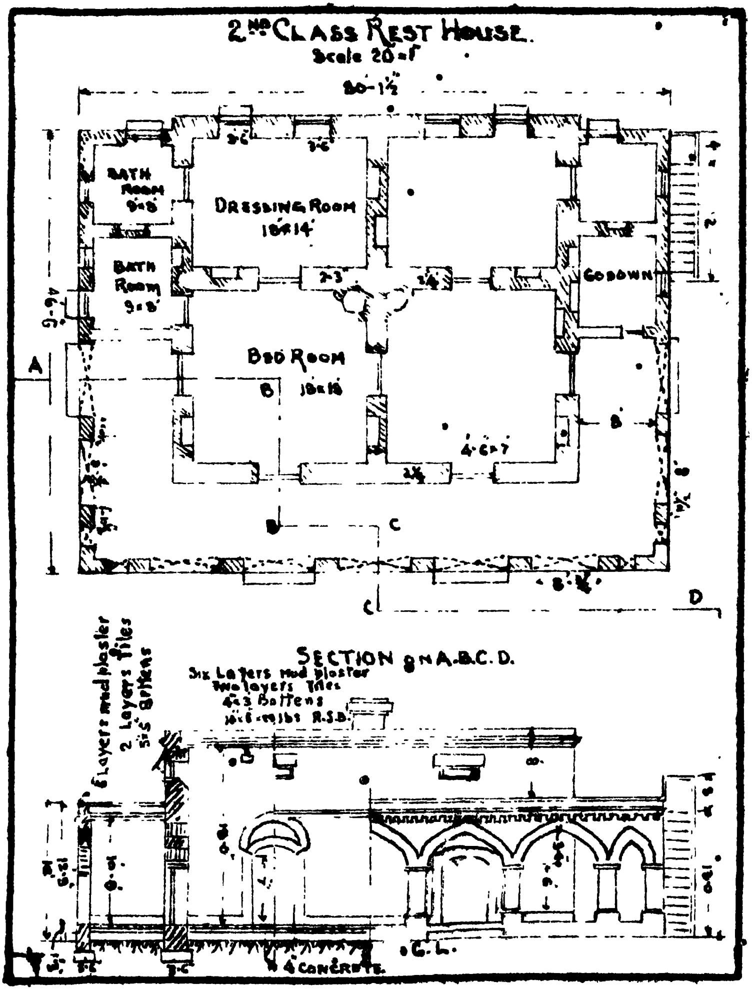


SECTION ON A.B.



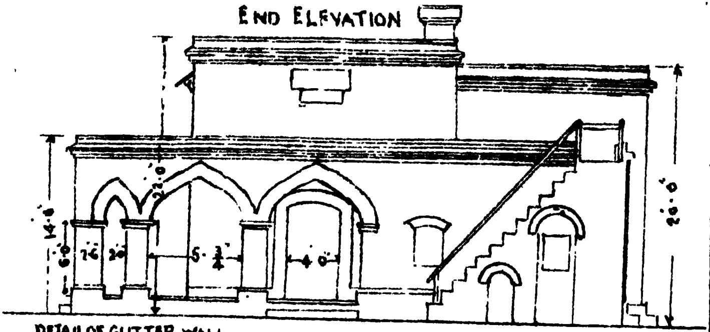

PLAN
BATH
OFFICE
GODOWN
BED ROOM
BATH ROOM
VERANDAH
SITTING ROOM
VERANDAH
VERANDAH
PART ELEVATION ON G H
FIRST CLASS REST HOUSE
Scale. 20 = 1


FIRST CLASS REST HOUSE
Scale 20=1"
SECTION ON A.B.C.
6 LAYERS MUD PLASTER
2 LAYERS TILES
BATTENS
concrete flooring
DETAIL OF GUTTER WALL
DETAIL FOR SLOPING VERANDAH
5x5
SECTION ON D.E.F.
ARCH IN SITTING ROOM
5 LAYERS MUD PLAST
2 LAYERS TILES
3x3 BATTENS
4" concrete flooring

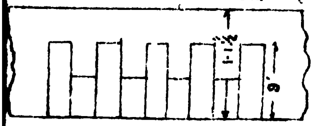

2ND CLASS REST HOUSE.
Scale 20=1"
BATH ROOM 9×8
DRESSING ROOM 18×14
BATH ROOM 9×8
GODOWN
BED ROOM 18×15
SECTION ON A.B.C.D.
Six Layers mud plaster
Two layers Tiles
4×3 Battens
G.L.
4" CONCRETE.

SECOND CLASS REST HOUSE.

END ELEVATION

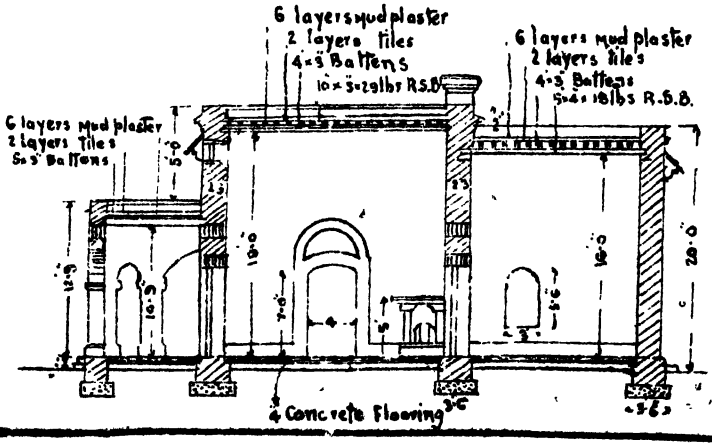


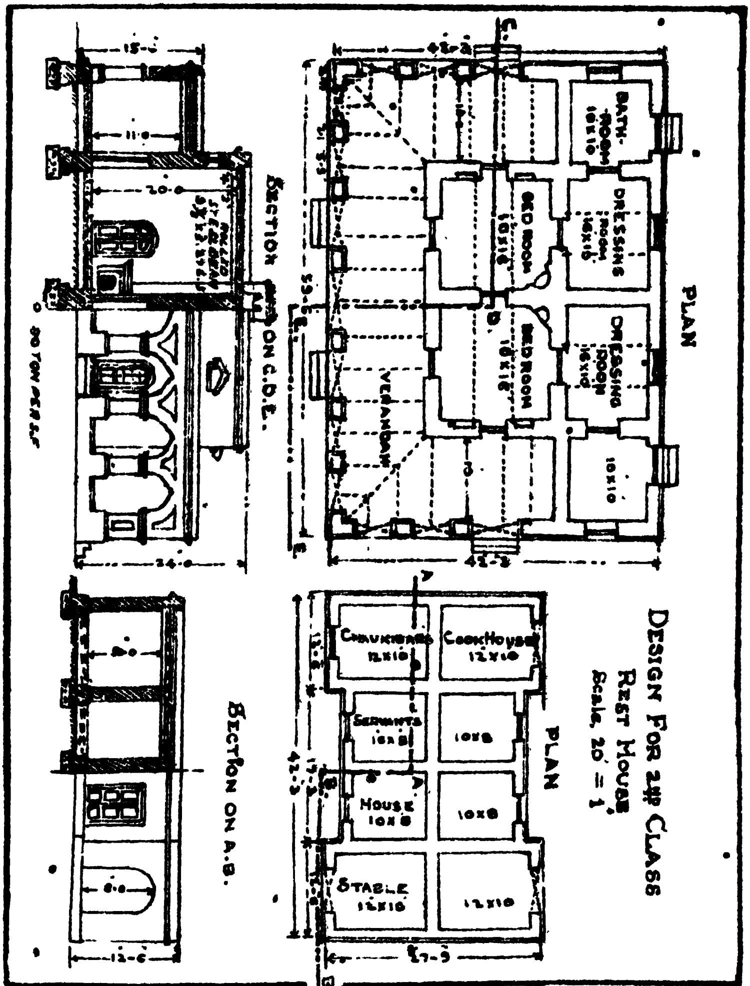
DETAIL OF GUTTER WALL



Scale. 20' = 1"

SECTION ON E.F.



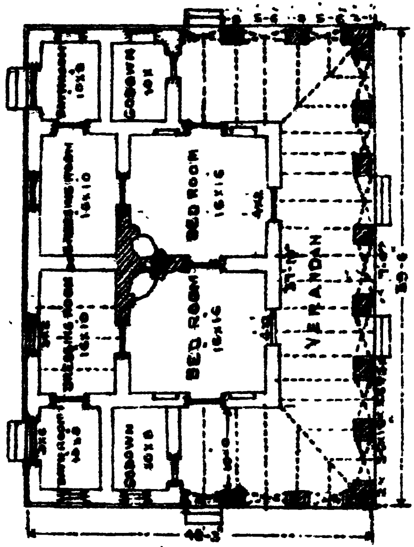

DESIGN FOR 2ND CLASS
REST HOUSE
Scale, 20' = 1"
PLAN
BATH-ROOM 10x10
DRESSING ROOM 16x16
BED ROOM 16x16
BED ROOM 16x16
DRESSING ROOM 16x10
10x10
VERANDAH
PLAN
CHAUKIDARS 12x10
COOK HOUSE 12x10
SERVANTS 10x8
10x8
HOUSE 10x8
10x8
STABLE 12x10
12x10
SECTION ON C.D.E.
SECTION ON A.B.

ALTERNATE DESIGN

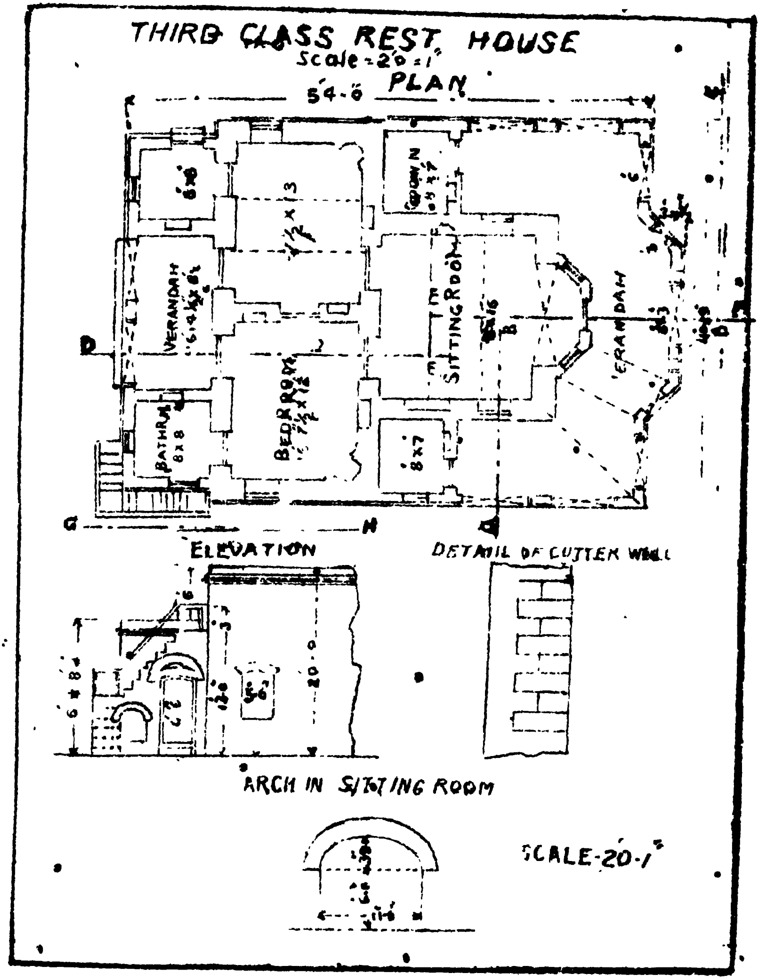
2nd CLASS REST HOUSE

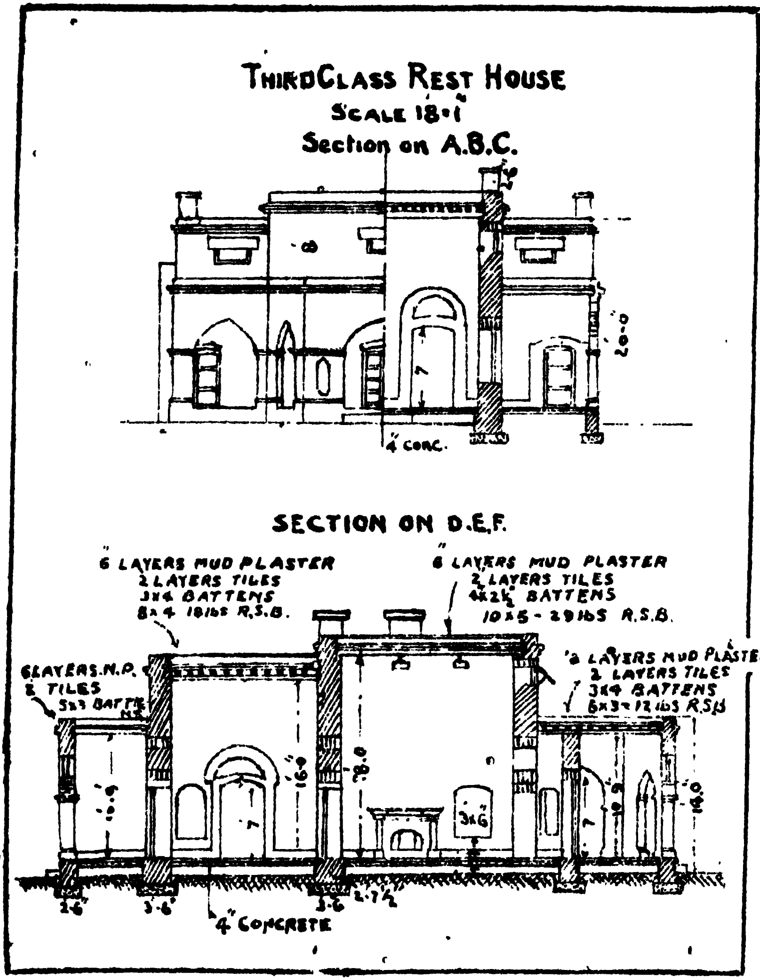
Scale 30 = 1

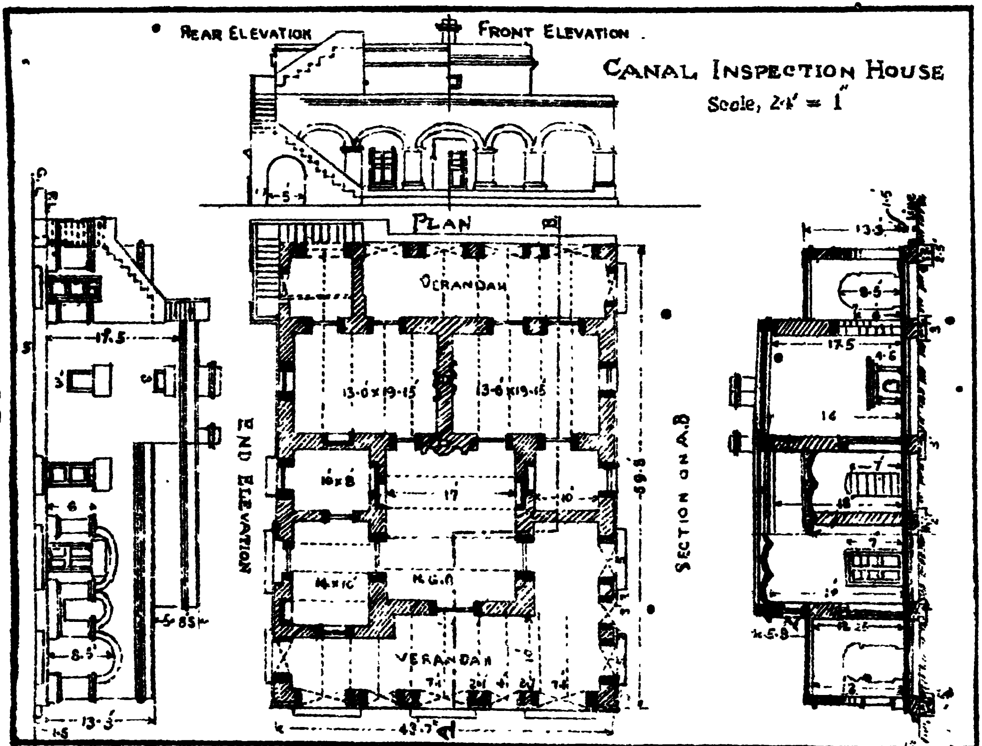
PLAN



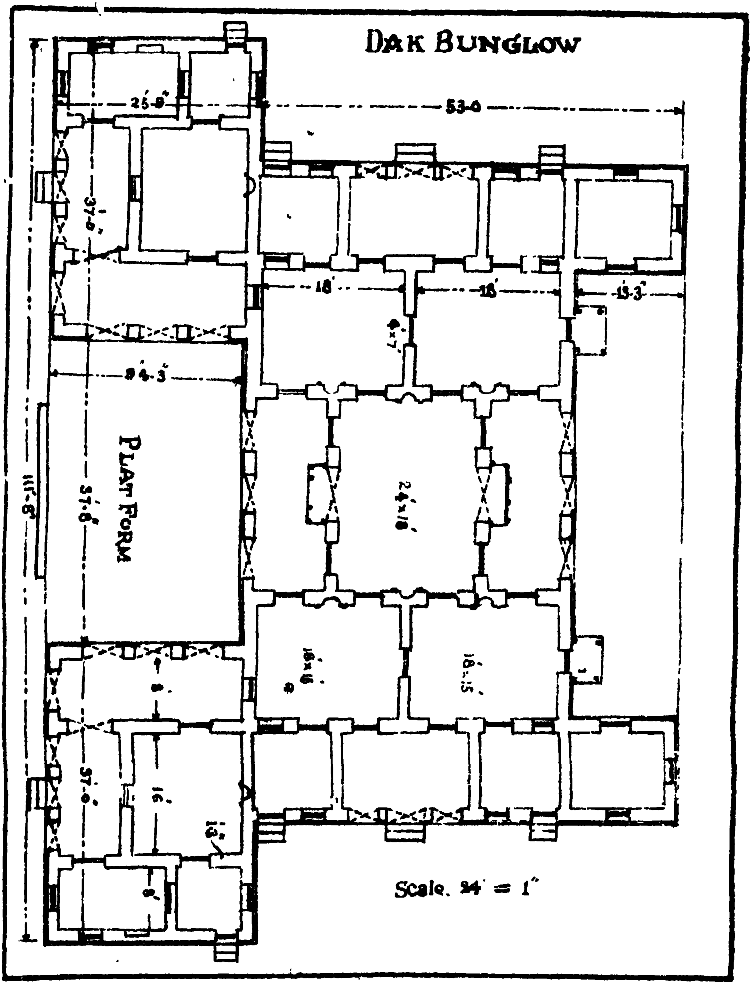
ITEM No.	PARTICULARS	QUANTITY
I	EARTH WORK	6802
II	CONCRETE	1960
III	BURNT BRICK IN LINE	685
IV	DO IN MUD	5
V	SUNDRIED BRICK IN MUD	4439
VI	LIME POINTING	2256
VII	MUD PLASTER	8963
VIII	WHITE WASHING	8963
IX	TERRACE FLOORING	1971
X	1st CLASS ... FLOORING	2246
XI	STONE WORK	31
XII	DEODAR WOOD WORK	135
XIII	DOORS AND WINDOWS	437
XIV	CUP BOARDS	84
XV	ROLLED STEEL BEAMS	52075
XVI	SUN SHADES	4

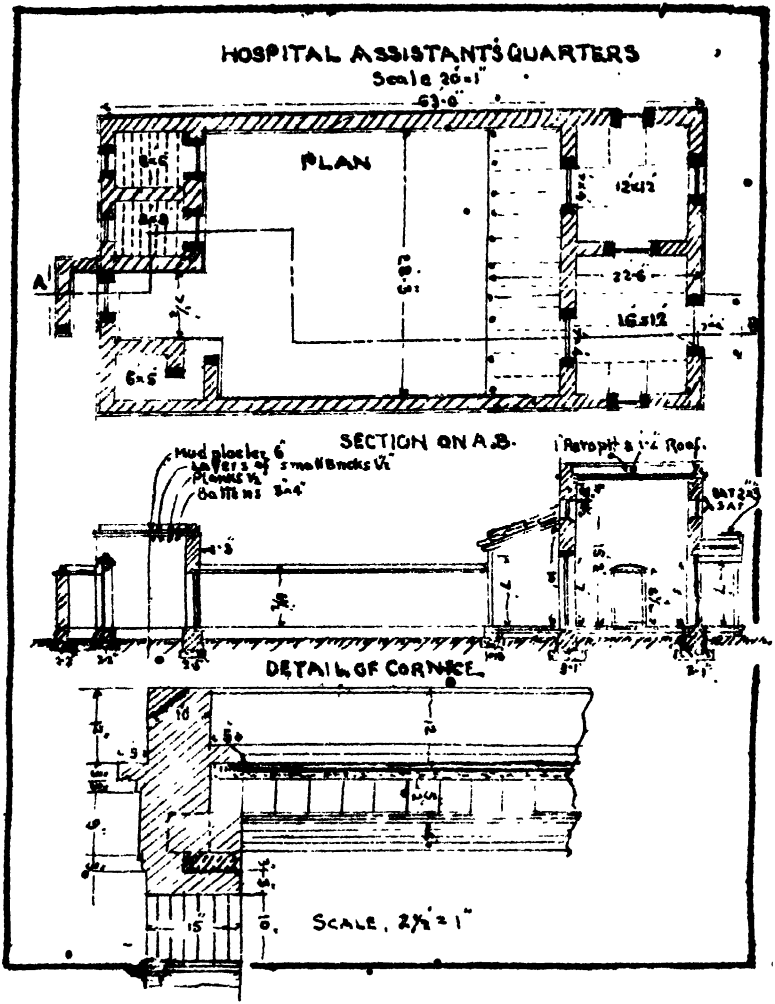

THIRD CLASS REST HOUSE
Scale = 20' = 1"
PLAN
54'-0"
VERANDAH
BATHRM 8x8
BEDROOM
SITTING ROOM
ELEVATION
DETAIL OF GUTTER WALL
ARCH IN SITTING ROOM
SCALE-20'-1"

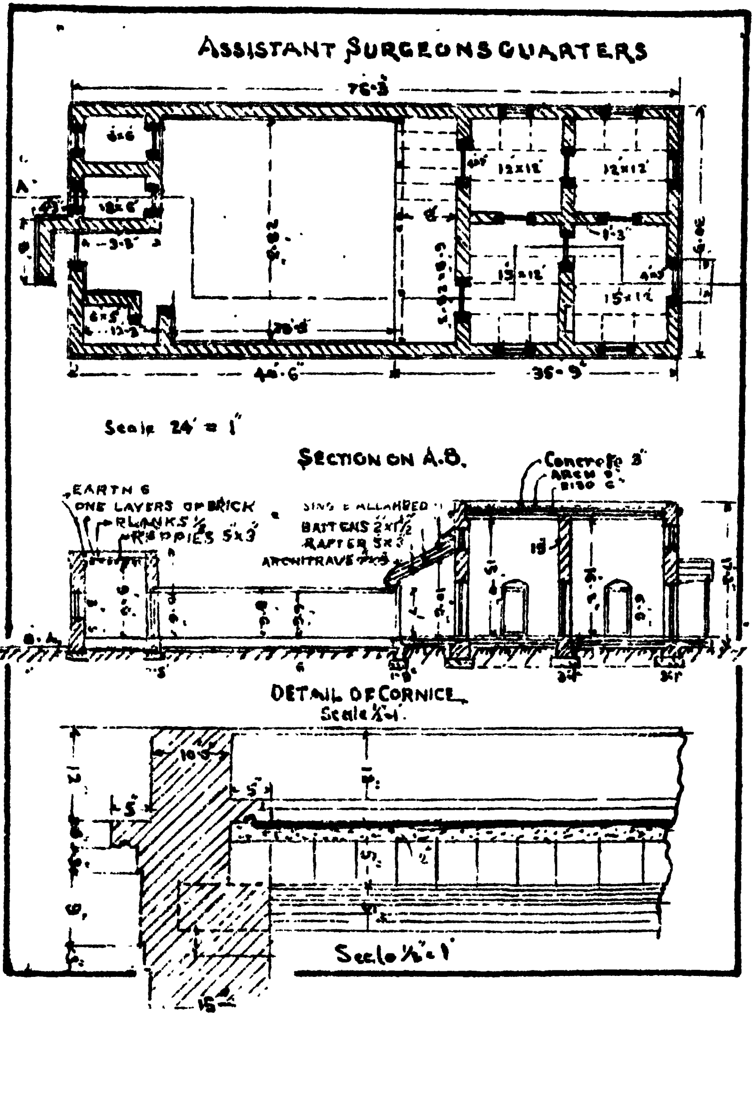

THIRD CLASS REST HOUSE
SCALE 18=1
Section on A.B.C.
4" CONC.
20-0
SECTION ON D.E.F.
6" LAYERS MUD PLASTER
2 LAYERS TILES
3x4 BATTENS
8x4 18lbs R.S.B.
6" LAYERS MUD PLASTER
2 LAYERS TILES
4x2½ BATTENS
10x5 - 29lbs R.S.B.
6 LAYERS M.P.
2 TILES
3x3 BATTENS
3 LAYERS MUD PLASTER
2 LAYERS TILES
3x4 BATTENS
6x3 - 12 lbs R.S.J.
3x6
2-6
3-6
3-6
2-7½
4" CONCRETE

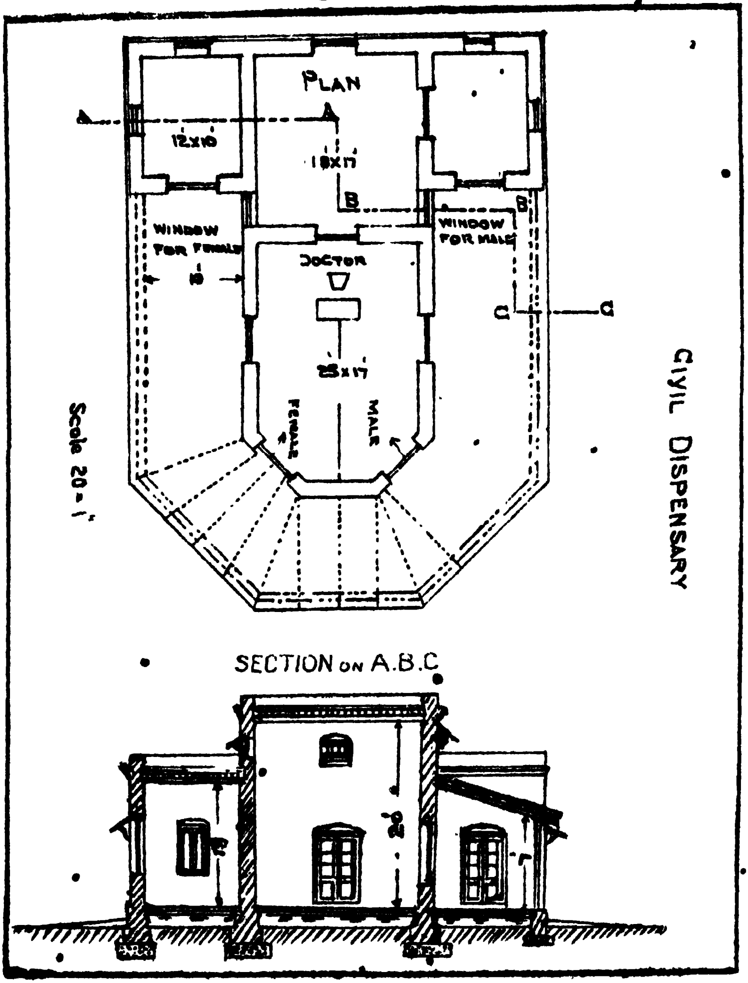


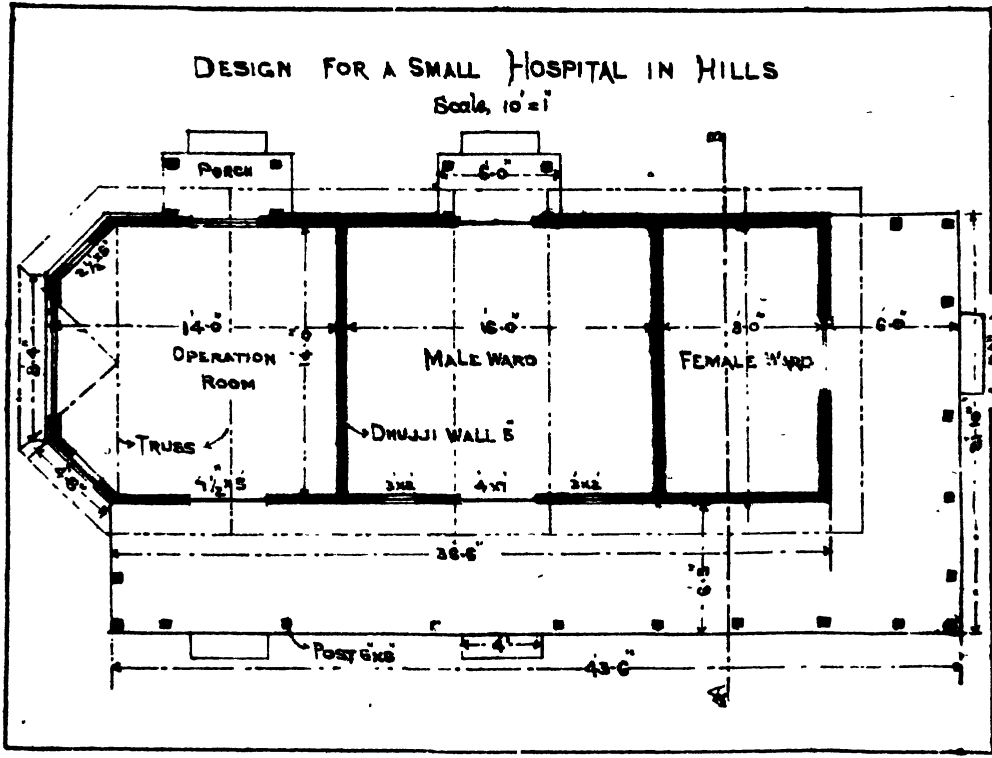
Canal Inspection House
Scale, 24′ = 1″


DAK BUNGLOW
25-9"
53-0
37-6"
18
18
13-3"
6×7
24-3"
PLAT FORM
57-6"
111-8"
24×18
16×16
16×15
8
57-6"
16
13"
8
Scale. 24' = 1"


HOSPITAL ASSISTANT'S QUARTERS
Scale 20'=1"
63-0"
PLAN
12x12
22-6
16x12
6x5
SECTION ON A.B.
Mud plaster 6"
Layers of small bricks 1½"
Planks 1½"
Battens 3x4"
DETAIL OF CORNICE
SCALE, 2½'=1"

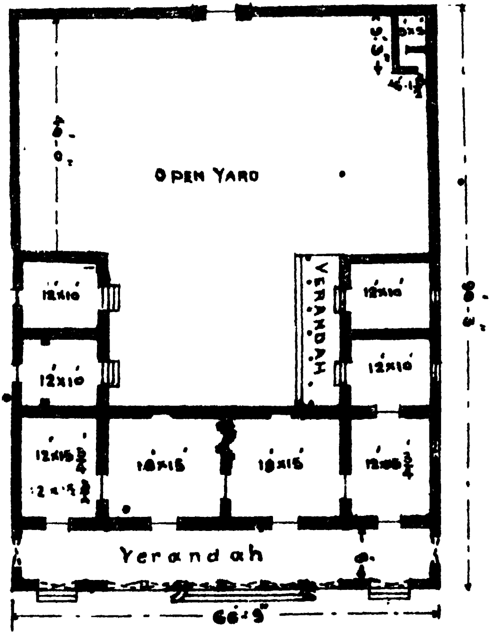

ASSISTANT SURGEONS QUARTERS
76-3
12x12
12x12
15x12
15x12
40-6
35-9
Scale 24' = 1"
SECTION ON A.B.
Concrete 3"
EARTH 6
ONE LAYERS OF BRICK
PLANKS ½
REPPIES 5x3
BATTENS 2x1½
RAFTER 5x3
ARCHITRAVE
DETAIL OF CORNICE
Scale ½"=1'
Scale ½"=1'


PLAN
12x10
18x17
WINDOW FOR FEMALE
WINDOW FOR MALE
DOCTOR
25x17
FEMALE
MALE
Scale 20 = 1"
CIVIL DISPENSARY
SECTION ON A.B.C


DESIGN FOR A SMALL HOSPITAL IN HILLS
Scale, 10'=1"
PORCH
6-0"
14-0"
OPERATION ROOM
TRUSS
MALE WARD
16-0"
DHUJJI WALL 5"
FEMALE WARD
8-0"
6-0"
36-6"
43-6"
POST 6"x8"
4'
3x2
4x7

SMALL DISPENSARY WITH INDIAN DOCTOR'S HOUSE

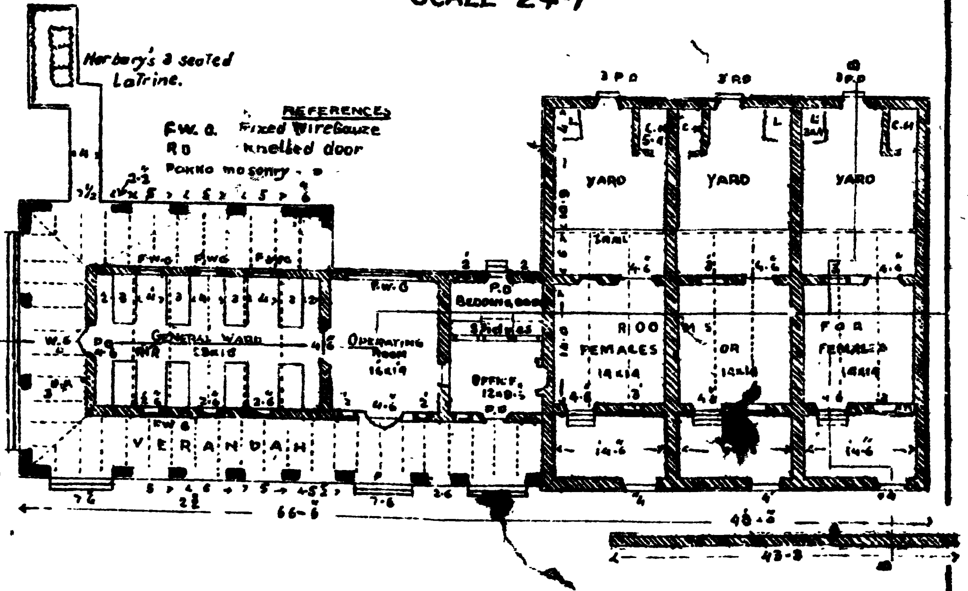
PLAN



Scale 30 Feet to 1 Inch

CIVIL HOSPITAL

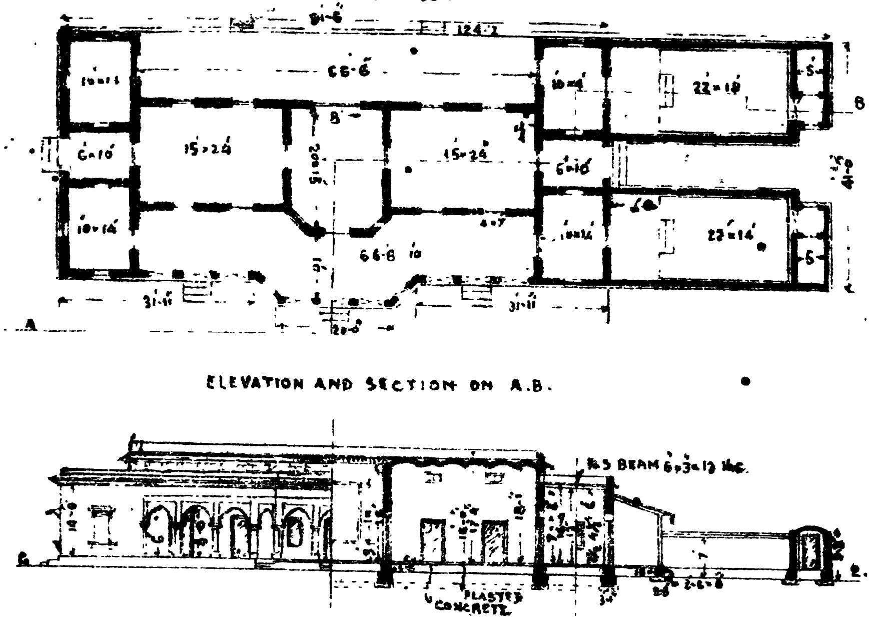
SCALE-24'-1"



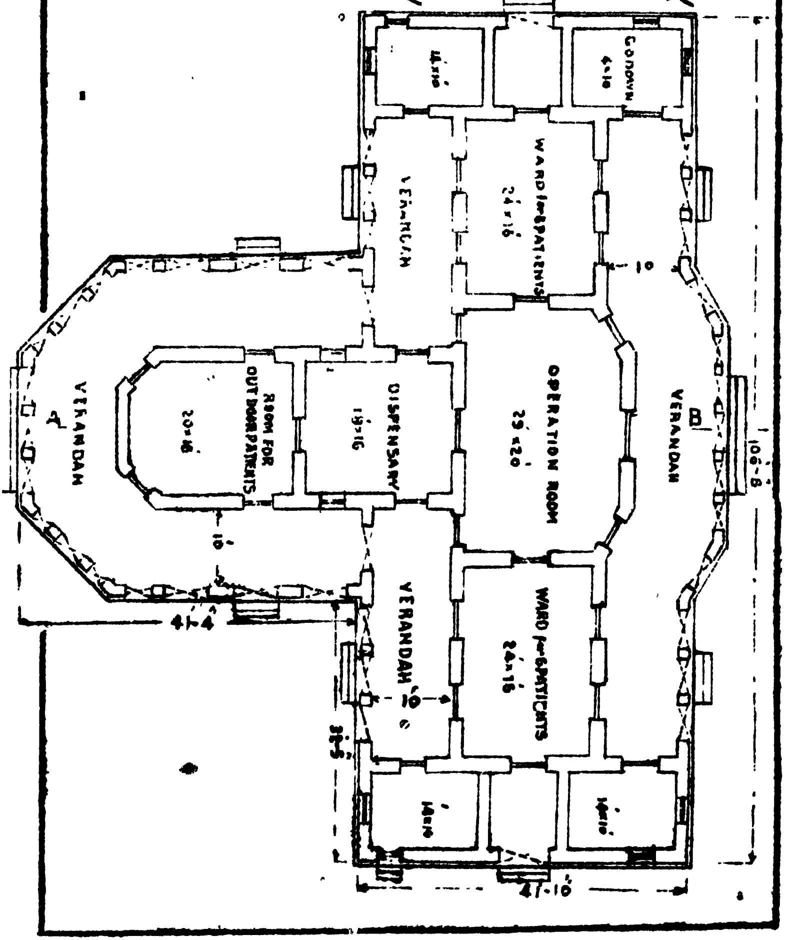
INDOOR WARD FOR TWELVE PATIENTS.

PLAN

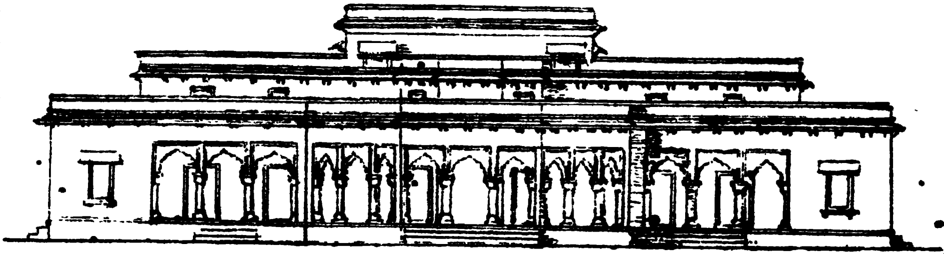
Scale 32=1



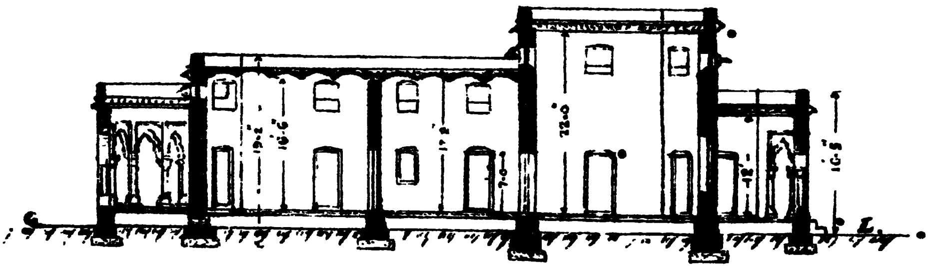
INDOOR WARD WITH DISPENSARY

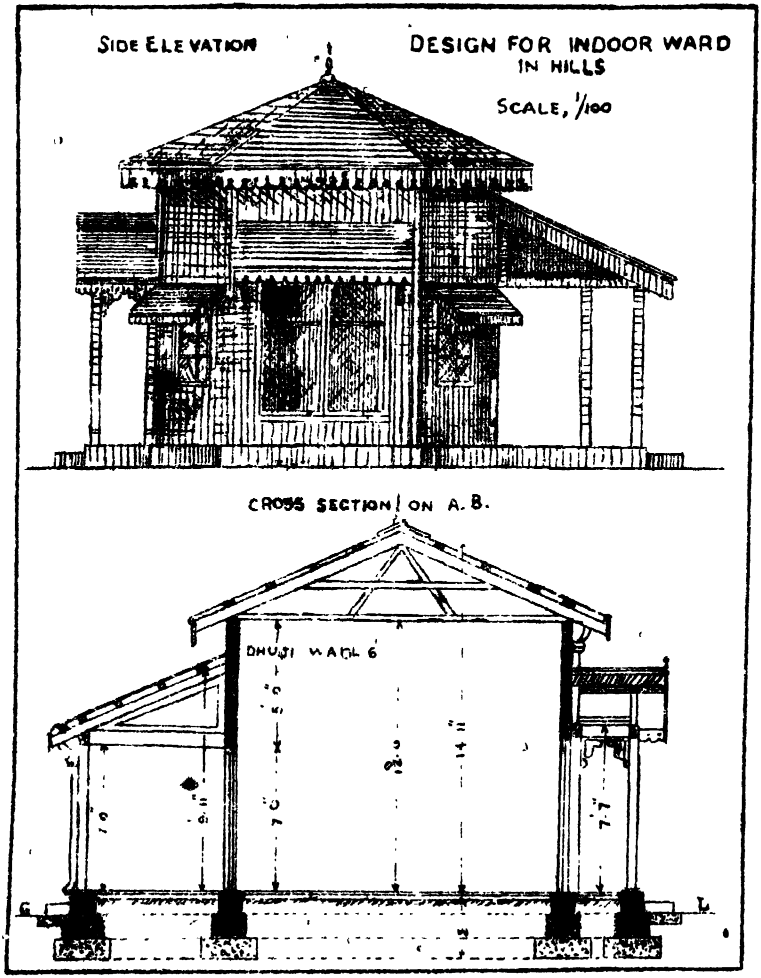


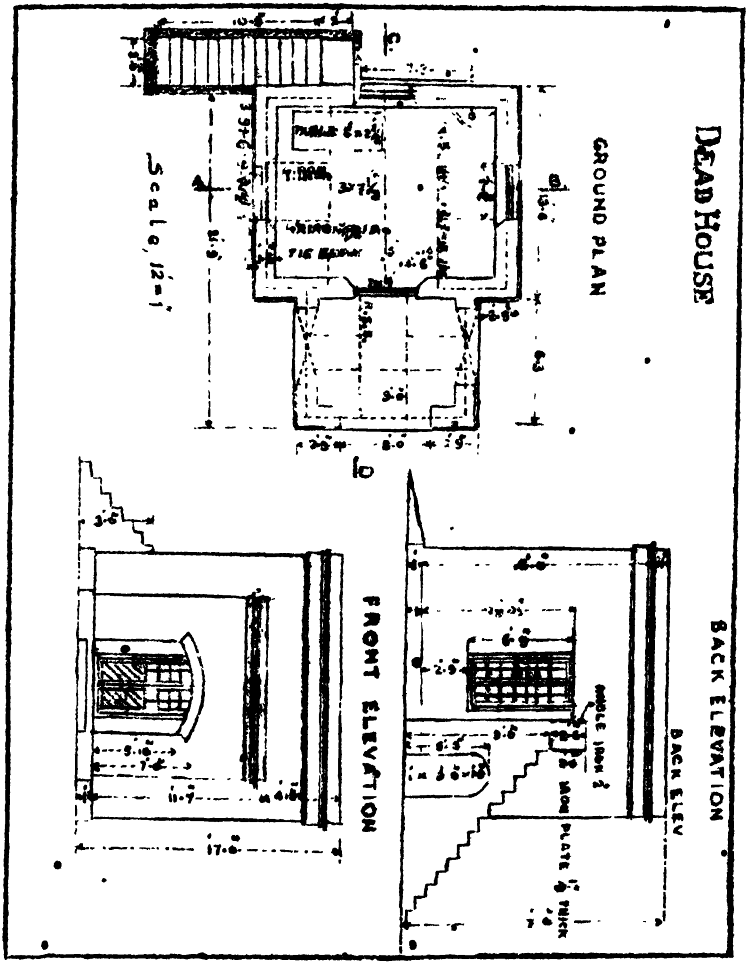
INDOOR WARD WITH DISPENSARY
Scale 24'=1"
ELEVATION

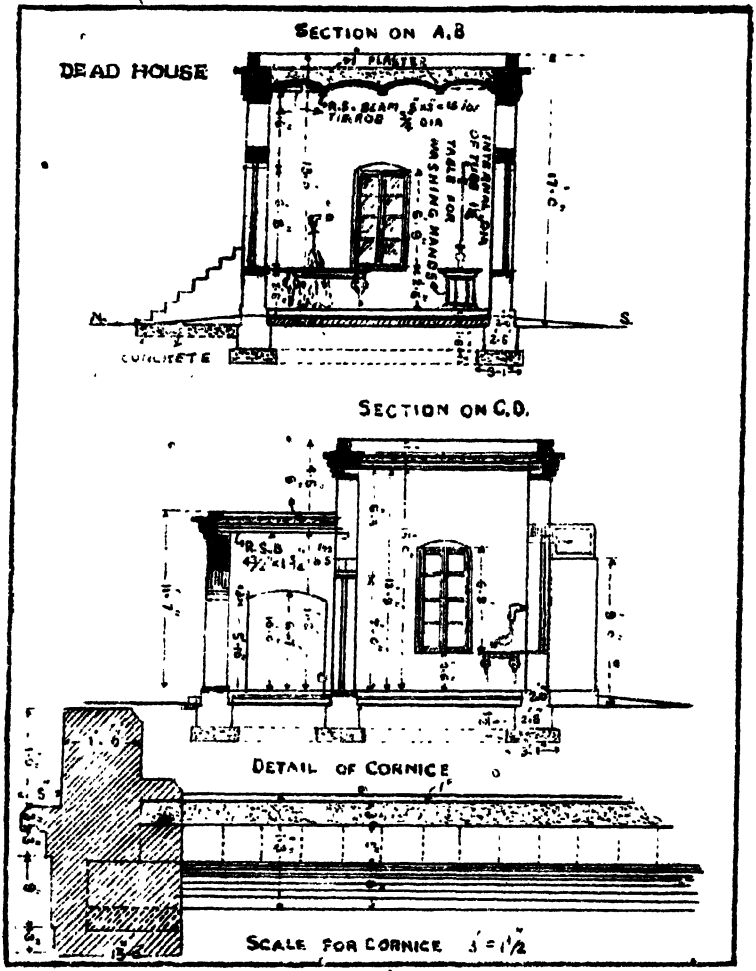


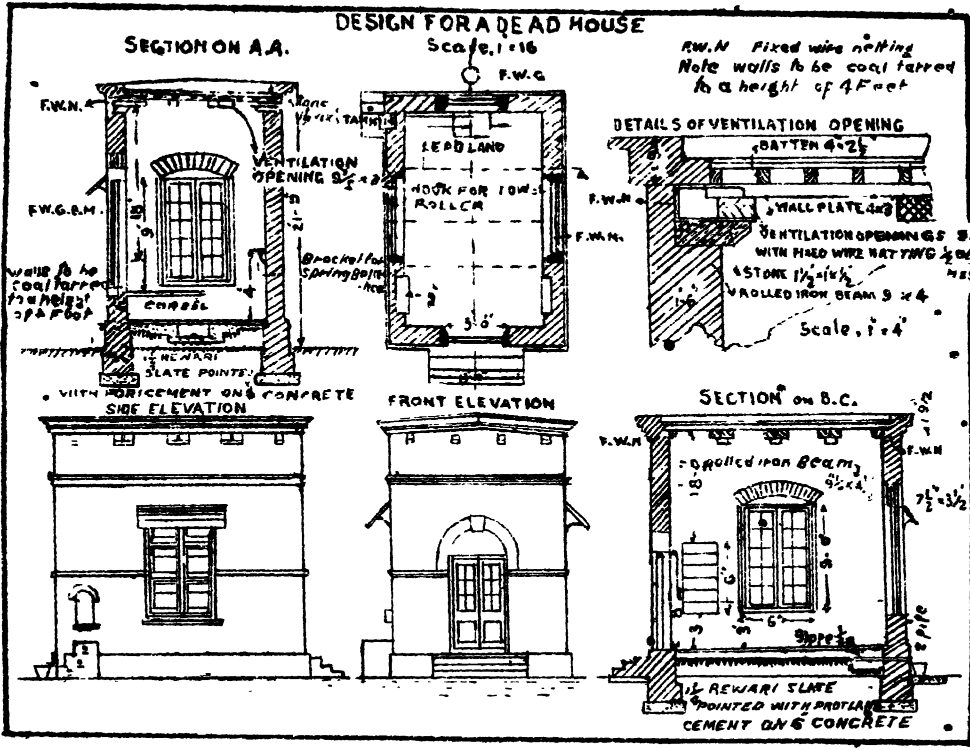
CROSS SECTION ON A.B.
Scale, 24'=1"

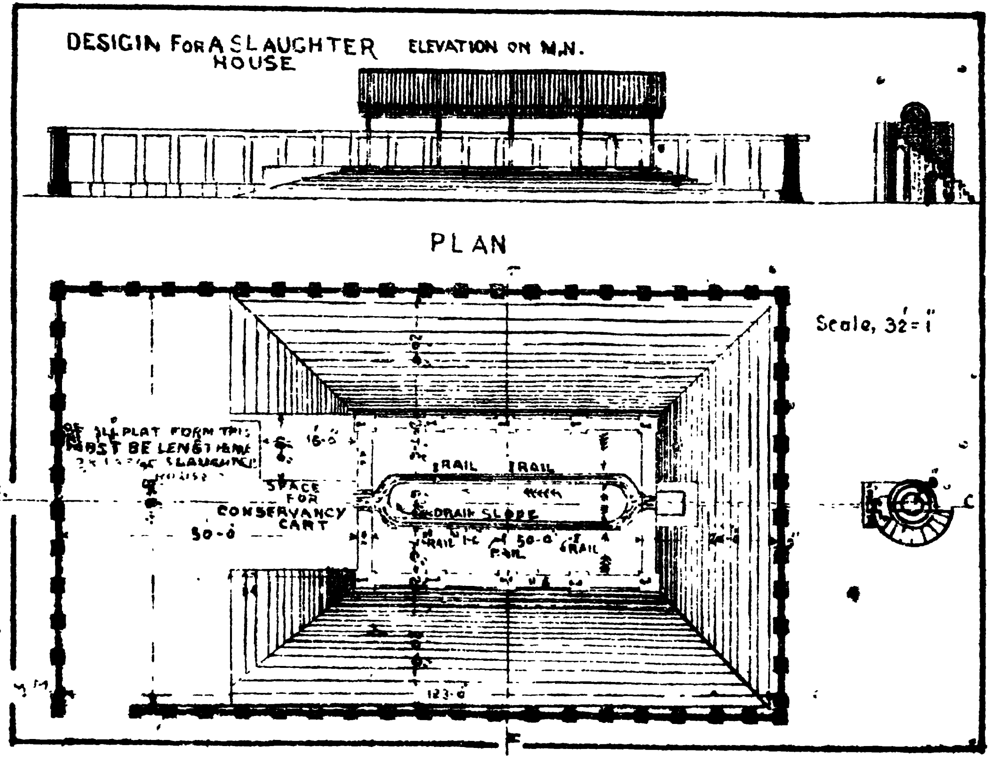


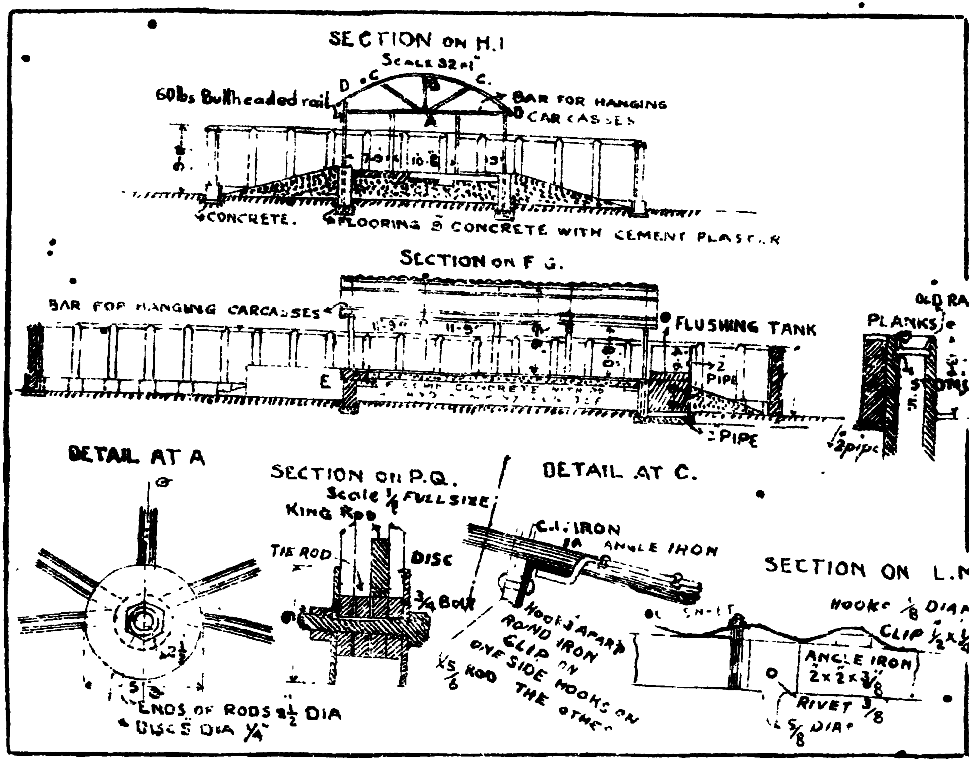

SIDE ELEVATION
DESIGN FOR INDOOR WARD
IN HILLS
SCALE, 1/100
CROSS SECTION ON A. B.

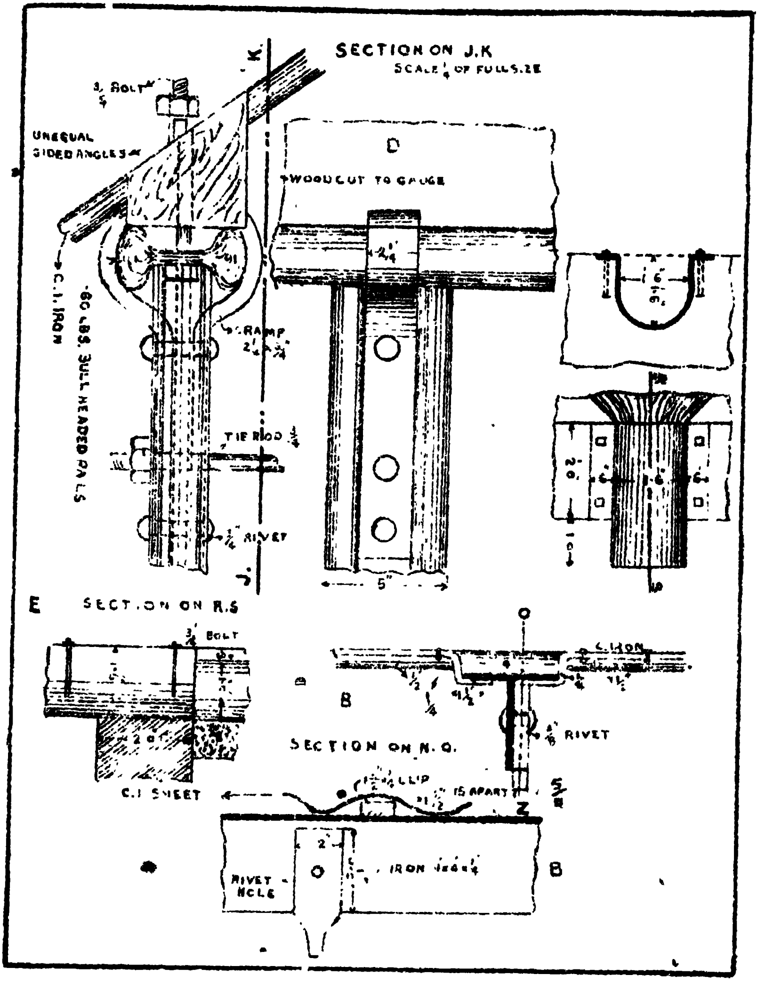

DEAD HOUSE
GROUND PLAN
Scale, 12'=1"
FRONT ELEVATION
BACK ELEVATION

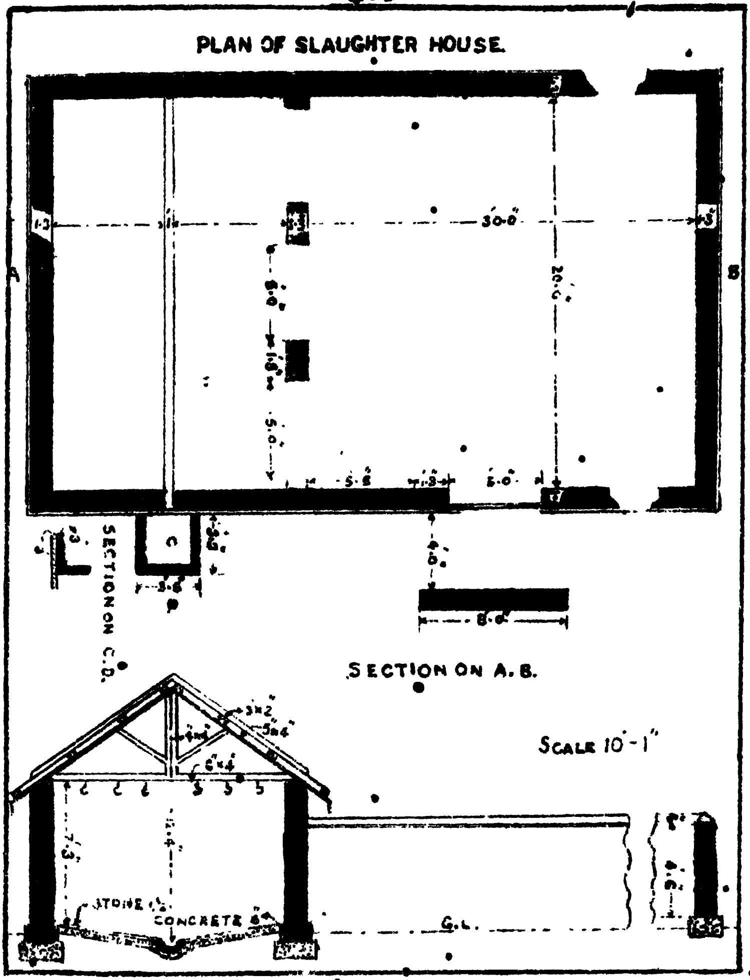

SECTION ON A.B
DEAD HOUSE
PLASTER
TIE ROD
TABLE FOR WASHING HANDS
SECTION ON C.D.
R.S.B
DETAIL OF CORNICE
SCALE FOR CORNICE

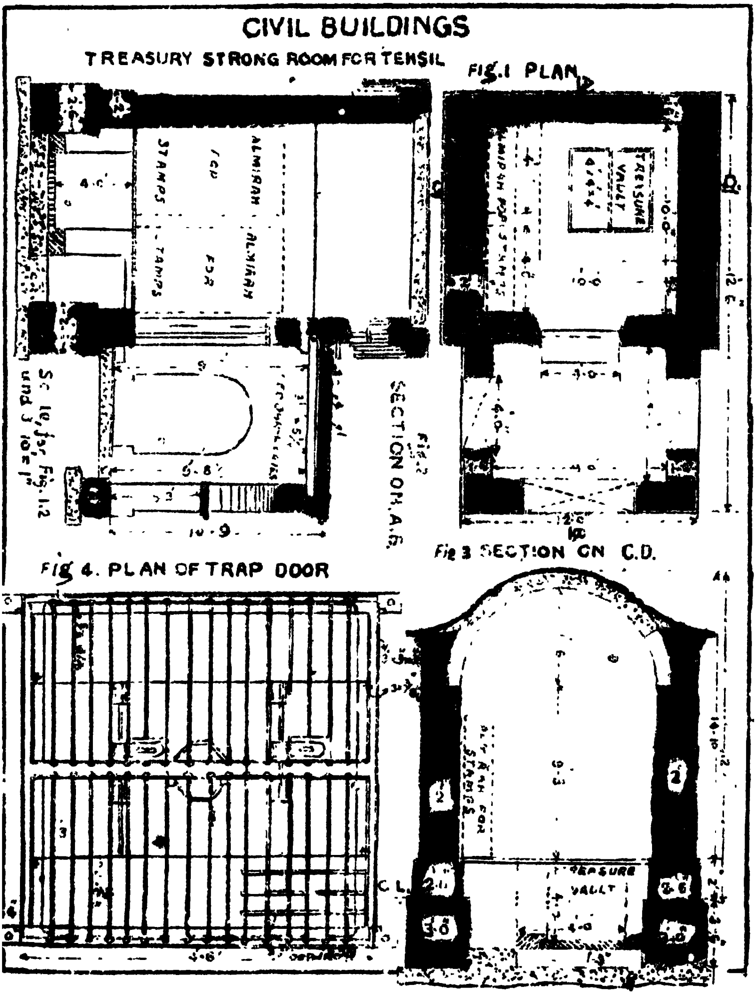

DESIGN FOR A DEAD HOUSE
Scale, 1:16
SECTION ON A.A.
F.W.N. Fixed wire netting
Note walls to be coal tarred to a height of 4 Feet
F.W.G
LEAD LAND
HOOK FOR TOWEL ROLLER
F.W.N.
F.W.G.B.M.
VENTILATION OPENING
CORBEL
SLATE POINTED
WITH CEMENT ON 6 CONCRETE
Bracket for spring bolt
walls to be coal tarred to a height of 4 Feet
DETAILS OF VENTILATION OPENING
BATTEN 4×2½
WALL PLATE
VENTILATION OPENINGS
WITH FIXED WIRE NETTING
MESH
ROLLED IRON BEAM 9×4
Scale, 1:4
SIDE ELEVATION
FRONT ELEVATION
SECTION ON B.C.
Rolled iron Beam
REWARI SLATE
POINTED WITH PORTLAND
CEMENT ON 6 CONCRETE
pipe


DESIGIN FOR A SLAUGHTER HOUSE
ELEVATION ON M.N.
PLAN
Scale, 32'=1"
SPACE FOR CONSERVANCY CART
50-0
16-0
RAIL
RAIL
DRAIN SLOPE
50-0
RAIL
123-0
MUST BE LENGTHENED
C
E


SECTION ON H.I
Scale 32=1"
60lbs Bullheaded rail
BAR FOR HANGING CARCASSES
CONCRETE.
FLOORING OF CONCRETE WITH CEMENT PLASTER
SECTION ON F G.
BAR FOR HANGING CARCASSES
FLUSHING TANK
PIPE
OLD RAIL
PLANKS
STONE
DETAIL AT A
ENDS OF RODS 2½ DIA
DISCS DIA ¼"
SECTION ON P.Q.
Scale ¼ FULL SIZE
KING ROD
TIE ROD
DISC
¾ BOLT
DETAIL AT C.
C.I. IRON
ANGLE IRON
HOOKS APART
ROUND IRON
CLIP ON
ONE SIDE HOOKS ON
THE OTHER
SECTION ON L.M.
HOOKS ⅛ DIAM
ANGLE IRON
2 x 2 x ⅜
RIVET ⅜
⅝ DIA


SECTION ON J.K
UNEQUAL SIDED ANGLES
C.I. IRON
WOOD CUT TO GAUGE
CRAMP
TIE ROD
RIVET
5"
E
SECTION ON R.S
BOLT
B
RIVET
SECTION ON N.O.
CLIP
15 APART
C.I. SHEET
RIVET HOLE
B


PLAN OF SLAUGHTER HOUSE
30·0"
20·0"
A
B
SECTION ON C.D.
SECTION ON A.B.
8·0"
STONE
CONCRETE
G.L.
SCALE 10'-1"


CIVIL BUILDINGS
TREASURY STRONG ROOM FOR TEHSIL
Fig.1 PLAN
ALMIRAH FOR STAMPS
TREASURE VAULT
SECTION ON A.B.
Fig.3 SECTION ON C.D.
Fig 4. PLAN OF TRAP DOOR
ALMIRAH FOR STAMPS
TREASURE VAULT

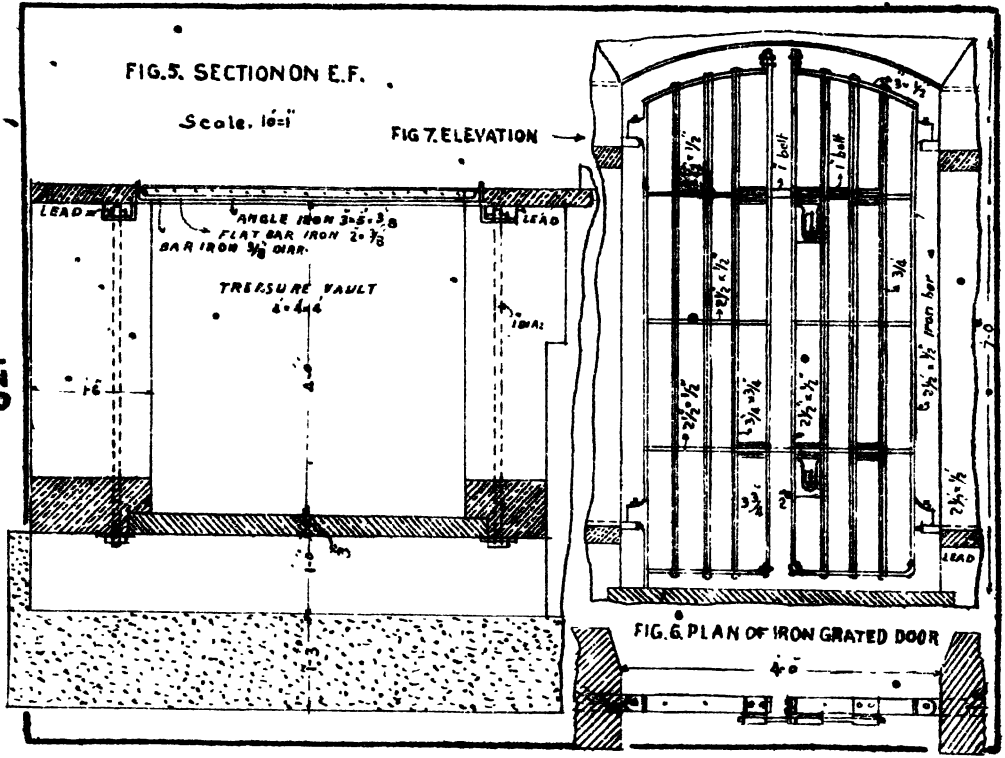
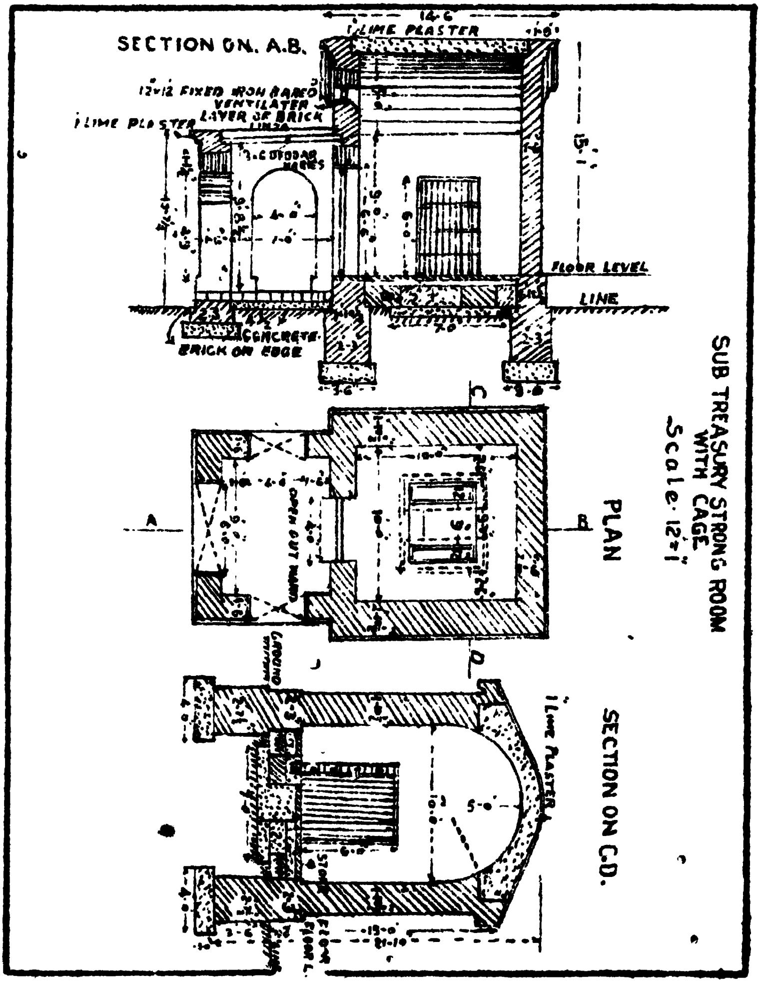


FIG. 5. SECTION ON E.F.

Scale. 16=1"

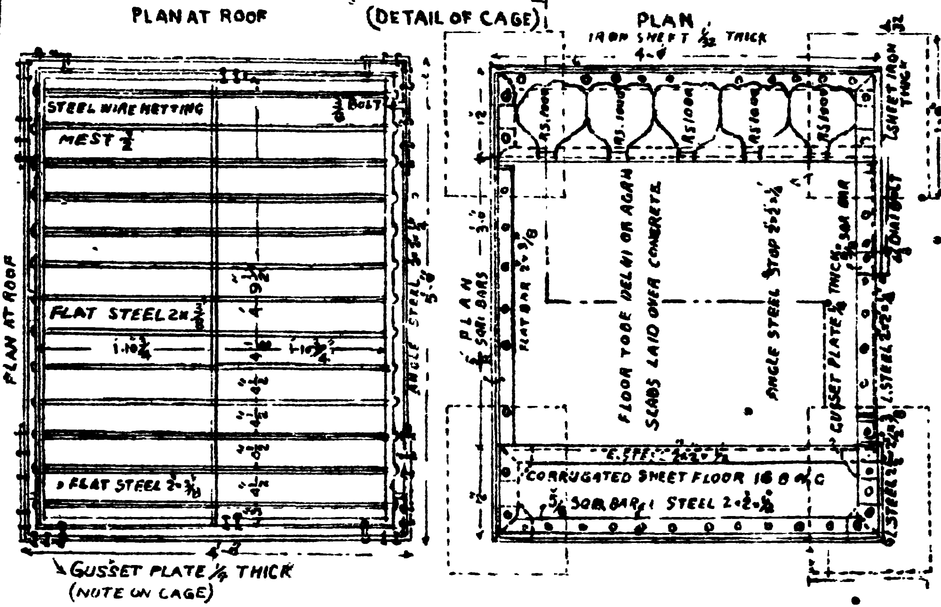
FIG 7. ELEVATION

FIG. 6. PLAN OF IRON GRATED DOOR


SECTION ON. A.B.
1 LIME PLASTER
12×12 FIXED IRON BARED VENTILATER
LAYER OF BRICK
FLOOR LEVEL
LINE
CONCRETE
BRICK ON EDGE
SUB TREASURY STRONG ROOM
WITH CAGE
Scale 12'=1"
PLAN
OPEN OUT WARD
SECTION ON C.D.
1 LIME PLASTER
GROUND
FLOOR L.

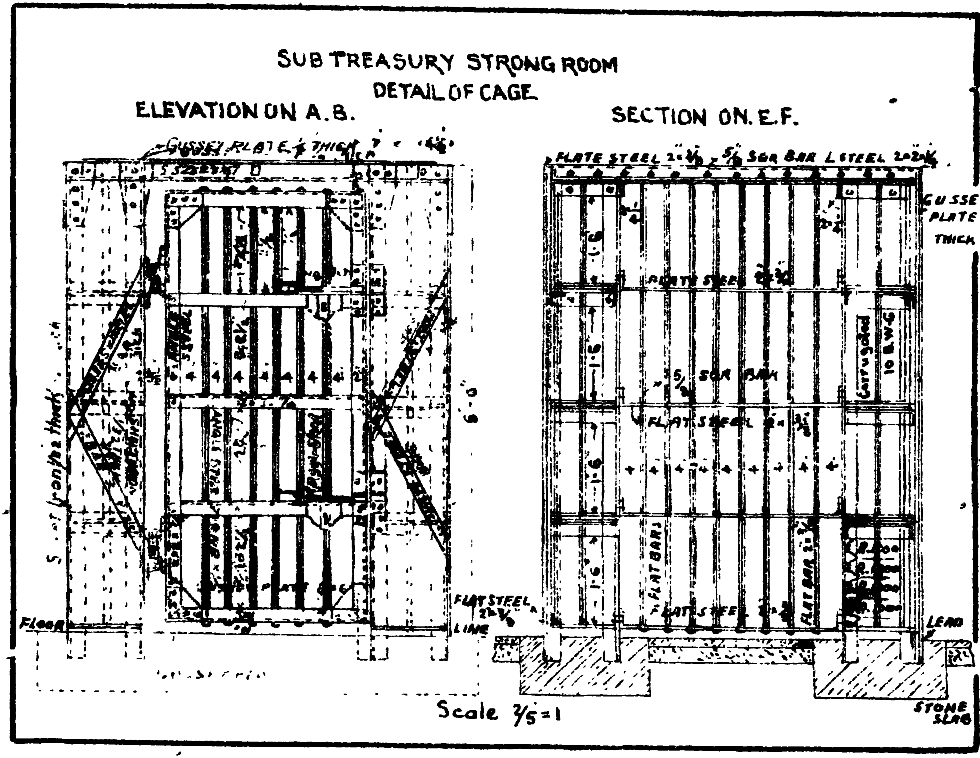
SUB TREASURY STRONG ROOM WITH CAGE

Scale. 12=1

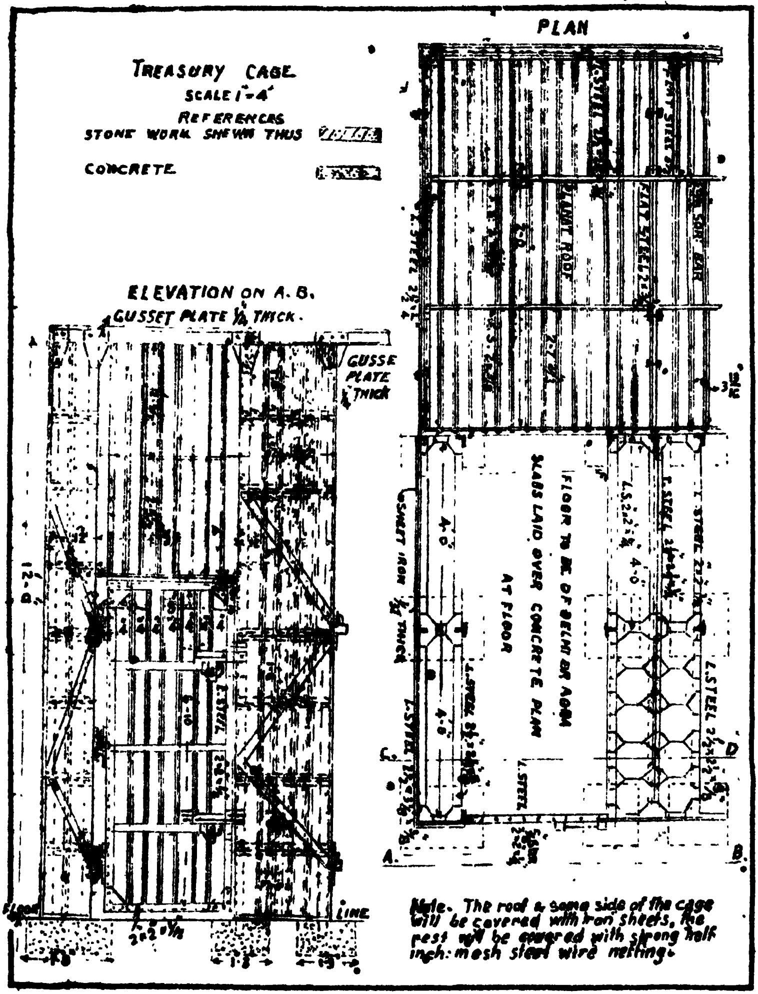


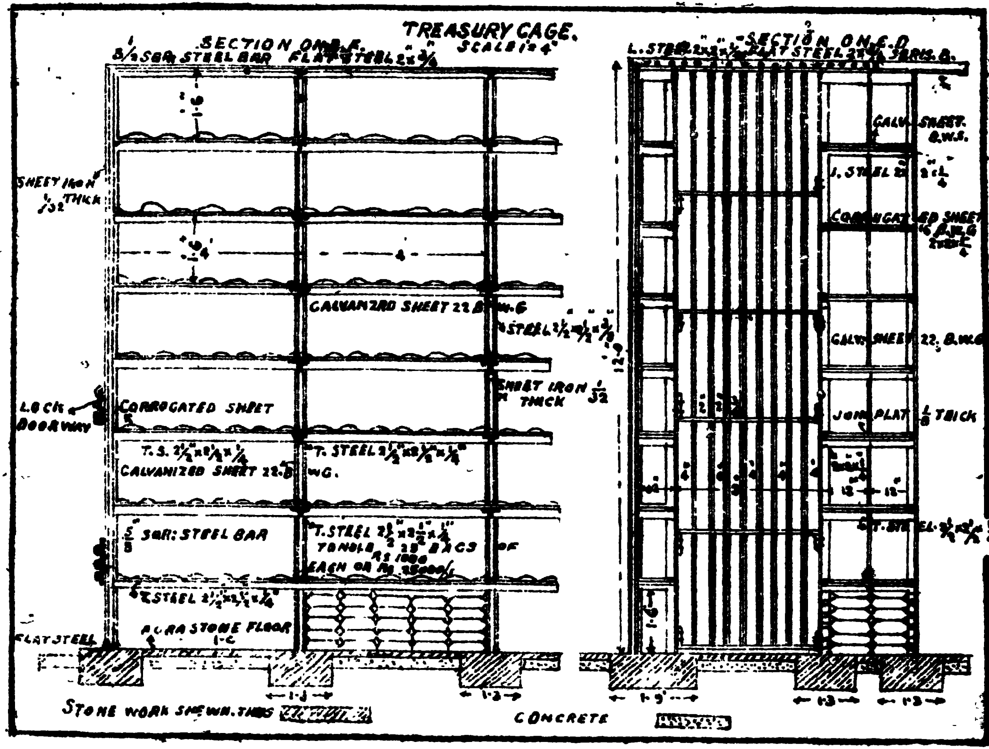
IN THIS DESIGN THERE ARE EIGHT COMPARTMENTS EACH COMPARTMENT IS CAPABLE OF CONTAINING 25 BAGS OF Rs. 1000 EACH
THEREFORE 8 COMPARTMENTS WILL HOLD 25000×8 = Rs. 2,00,000

624



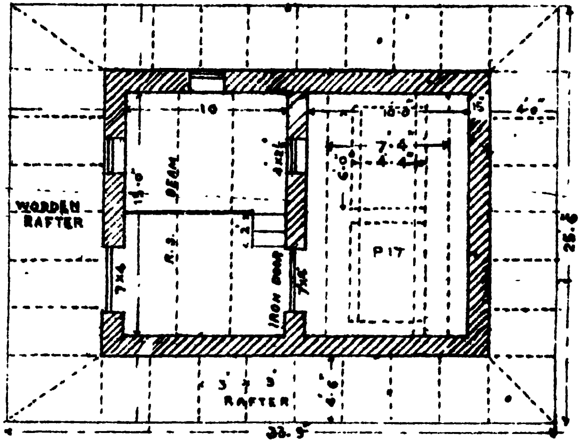
SUB TREASURY STRONG ROOM
DETAIL OF CAGE
ELEVATION ON A.B.
SECTION ON. E.F.
FLATE STEEL
5/8 SQR BAR
GUSSET PLATE ¼ THICK
5/8 SQR BAR
FLAT STEEL
FLAT BARS
Corrugated
10 B.W.G
6'-0"
1'-6
FLOOR
FLAT STEEL
LINE
LEAD
STONE SLAB
Scale 2/5=1


TREASURY CAGE
SCALE 1" = 4'
REFERENCES
STONE WORK SHEWN THUS
CONCRETE
PLAN
ELEVATION ON A. B.
GUSSET PLATE ¼" THICK.
GUSSET PLATE ¼" THICK
FLOOR
LINE
FLOOR TO BE OF BELMI BR AGRA SLABS LAID OVER CONCRETE PLAN AT FLOOR
SHEET IRON ⅛" THICK
A.
B.
C.
D.
Note. The roof & some side of the cage will be covered with iron sheets, the rest will be covered with strong half inch mesh steel wire netting.

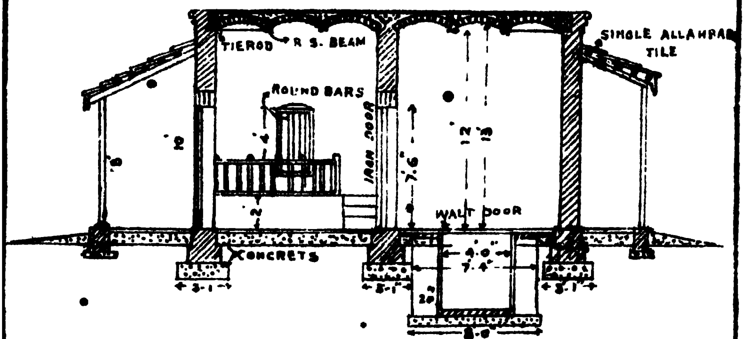

TREASURY CAGE.
SCALE 1" = 4'
SECTION ON A.B.
SECTION ON C.D.
SQR. STEEL BAR
FLAT STEEL
SHEET IRON 1/32 THICK
GALVANIZED SHEET 22 B.W.G.
SHEET IRON 1/32 THICK
LOCK
DOORWAY
CORRUGATED SHEET
5/8 SQR: STEEL BAR
ACRA STONE FLOOR
FLAT STEEL
STONE WORK SHEWN THUS
CONCRETE
GALV. SHEET
CORRUGATED SHEET
GALV. SHEET 22 B.W.G.
JOIN PLAT 1/8 THICK

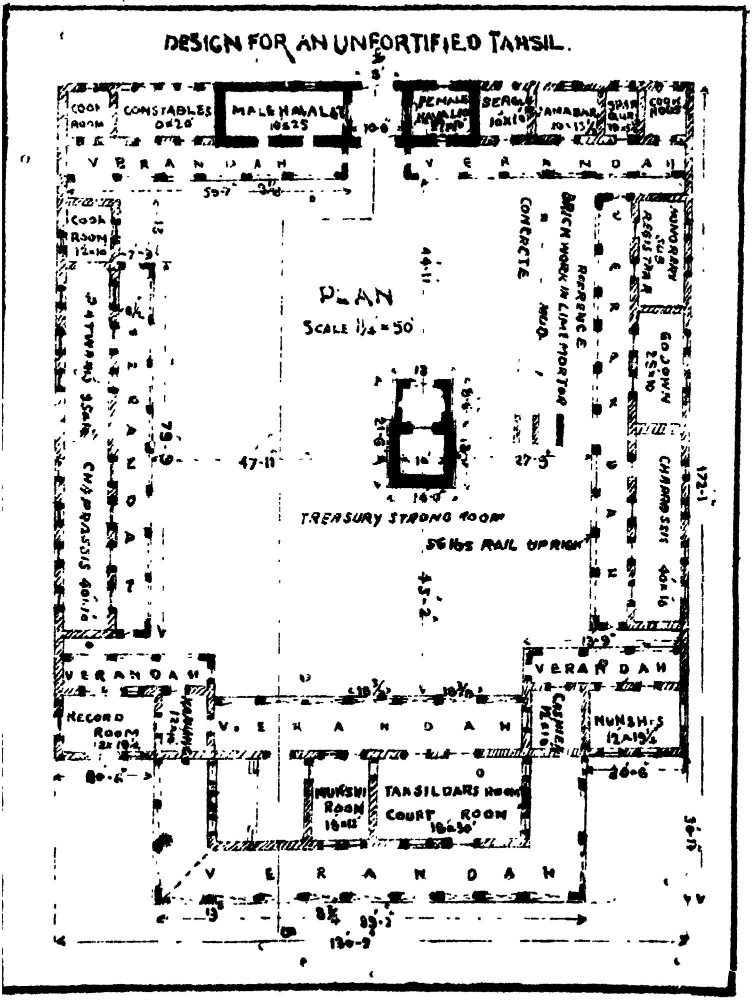
STANDARD PLAN FOR TREASURY

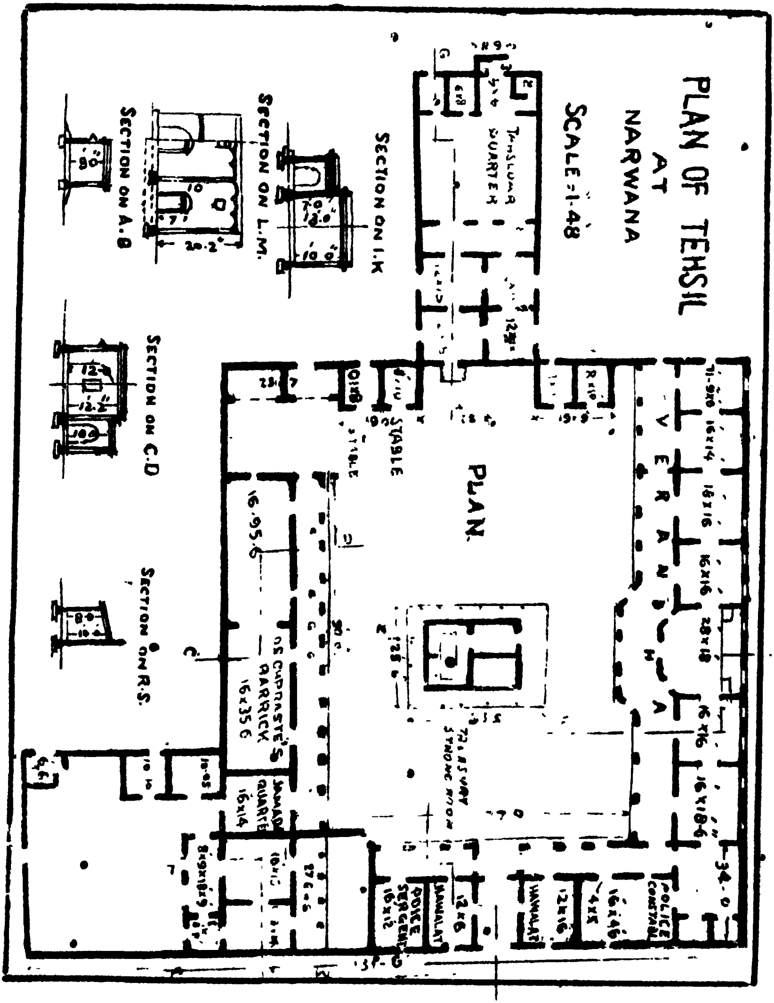
SCALE 12=1"

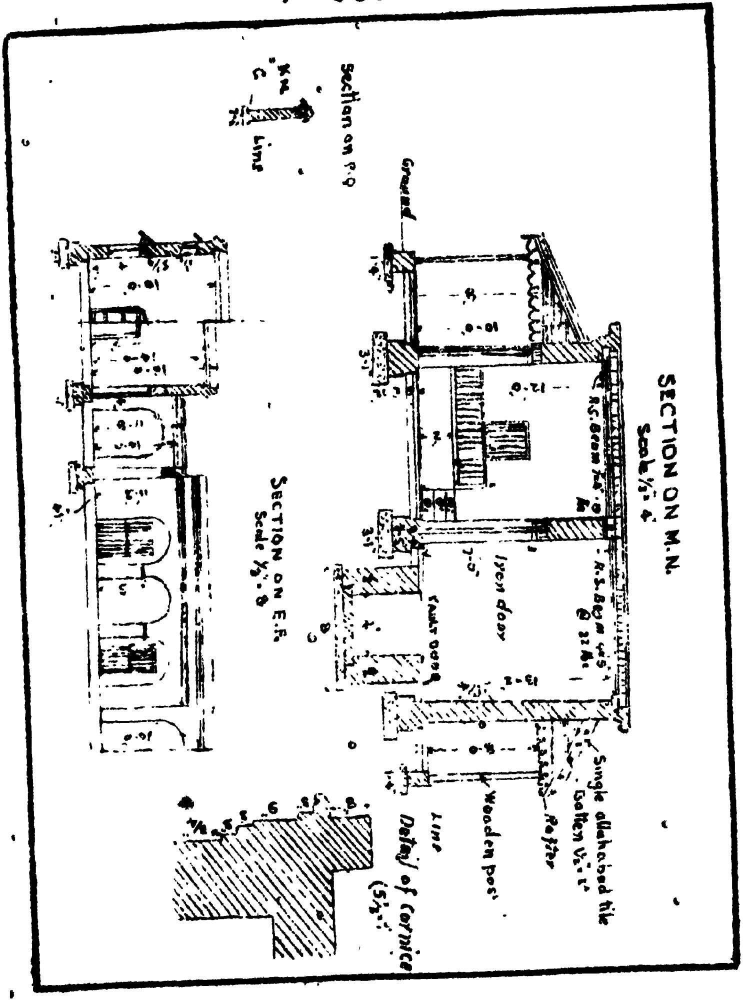


SECTION ON A.B.



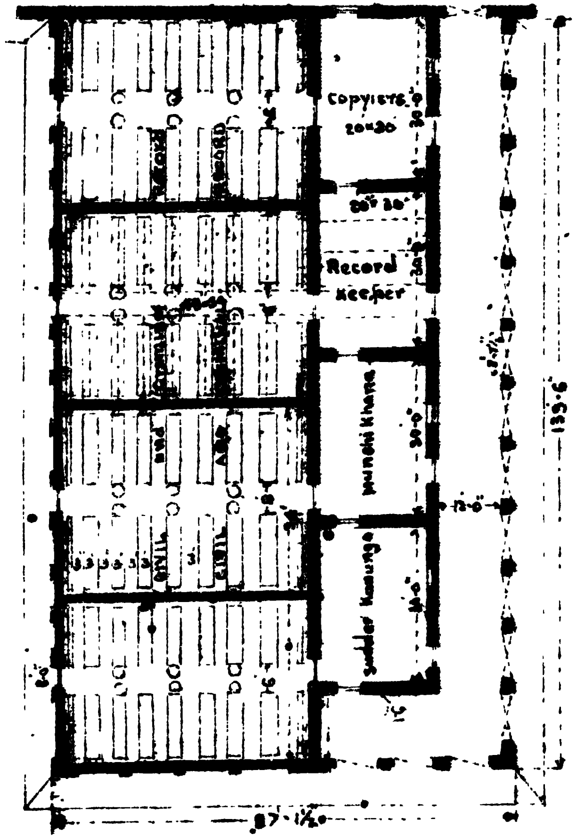

DESIGN FOR AN UNFORTIFIED TAHSIL.
PLAN
SCALE 1/4 = 50
CONSTABLES
MALE HAVALAT
FEMALE HAVALAT
VERANDAH
COOK ROOM
PATWARIS
CHAPRASSIS 40 x 16
TREASURY STRONG ROOM
56 lbs RAIL UPRIGHT
REFERENCE
BRICK WORK IN LIME MORTAR
CONCRETE
MUD
RECORD ROOM
NUNSHIS
CASHIER
MUNSHI ROOM
TAHSILDARS ROOM
COURT ROOM
GODOWN
HONORARY SUB REGISTRAR
136-9
172-1

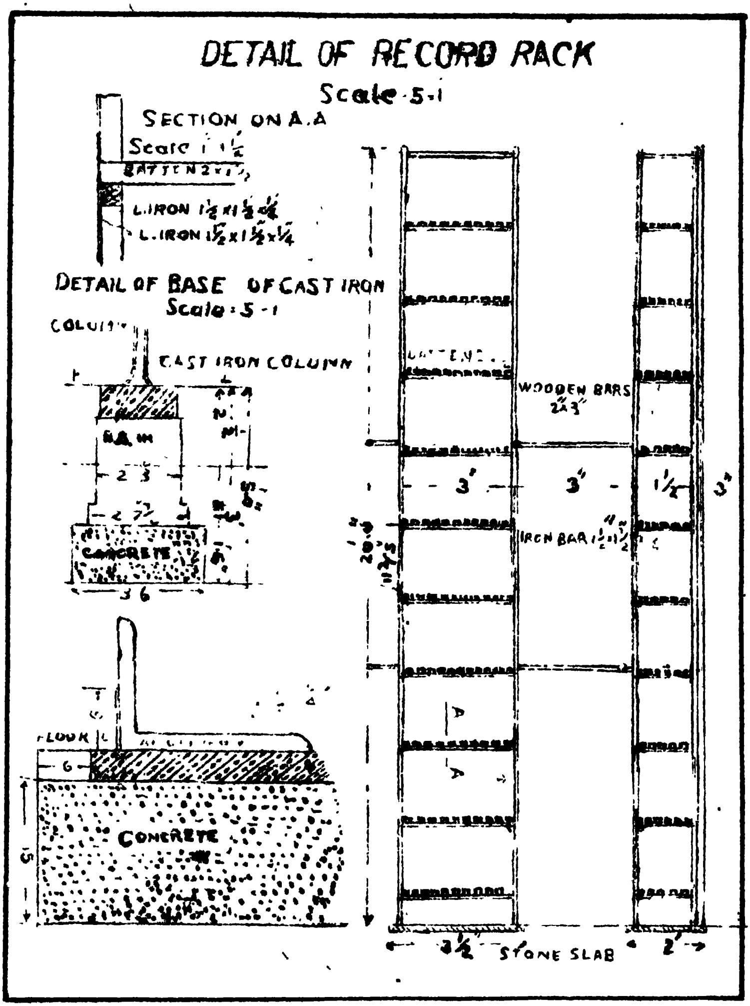

PLAN OF TEHSIL
AT
NARWANA
SCALE - 1·48
TEHSILDAR QUARTER
SECTION ON I.K
SECTION ON L.M.
SECTION ON A.B
SECTION ON C.D
SECTION ON R.S.
STABLE
PLAN
VERANDAH
TREASURY
STRONG ROOM
DUFTARSTE'S BARRICK
JAMADAR'S QUARTER
HAWALAT
POLICE SERGEANT
POLICE CONSTABLE

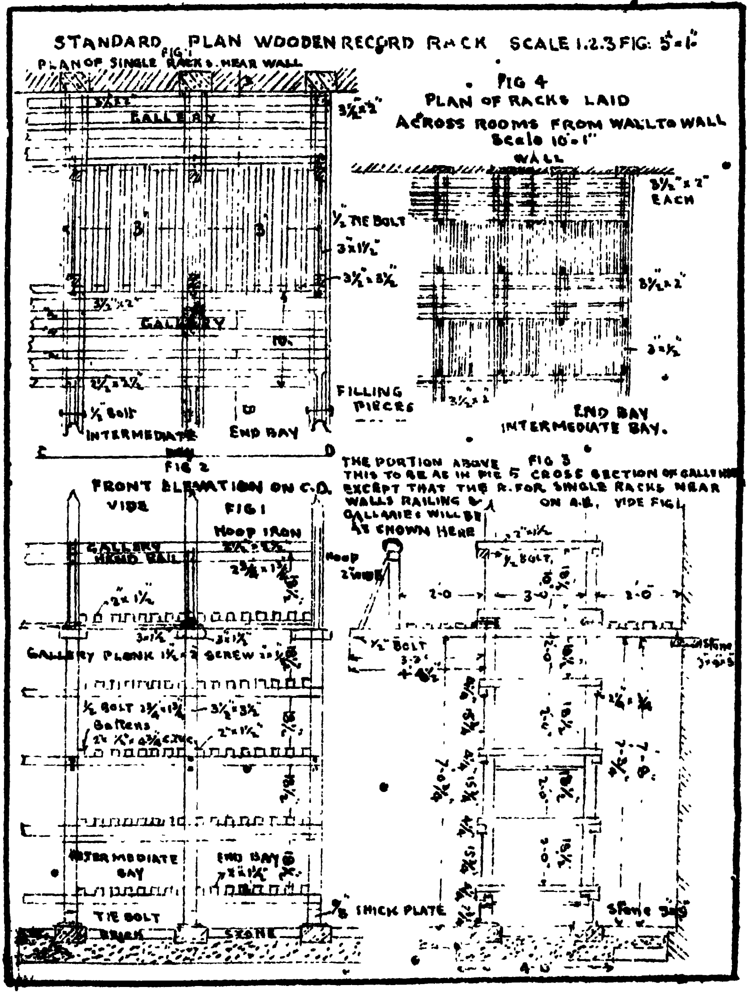

SECTION ON M.N.
Scale 1/8" = 4'
R.S. Beam
Iron door
Single allahabad tile
Batten
Rafter
Wooden post
Ground
Line
Detail of cornice
SECTION ON E.F.
Scale 1/8" = 8'
Section on P.Q

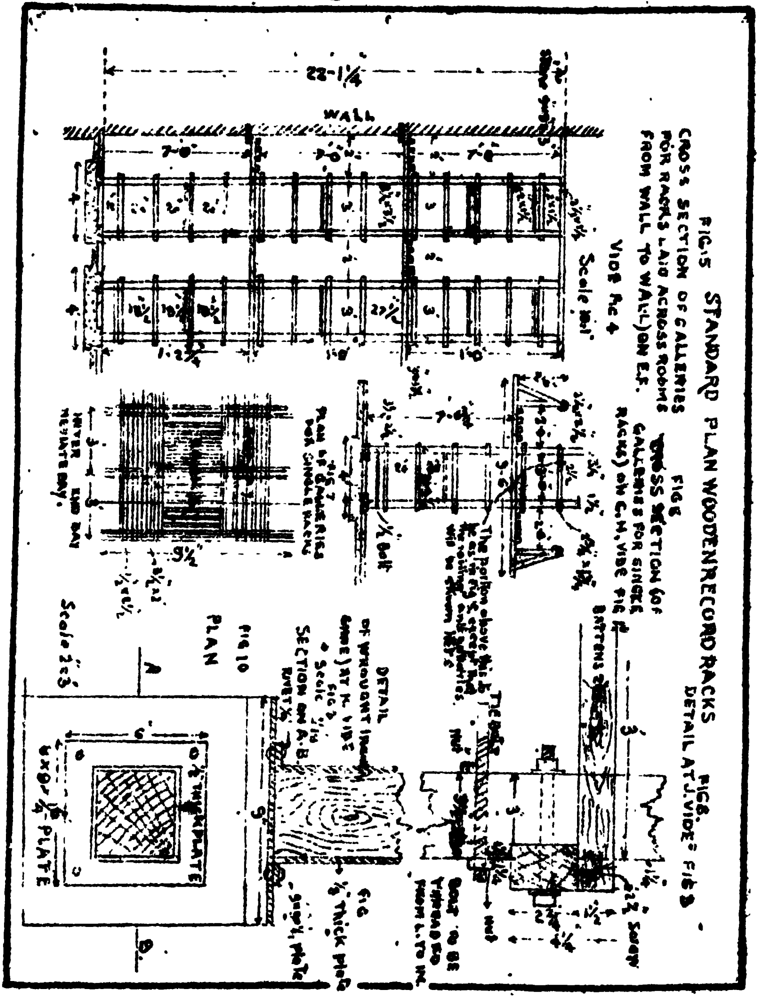
DESIGN FOR A RECORD RACK

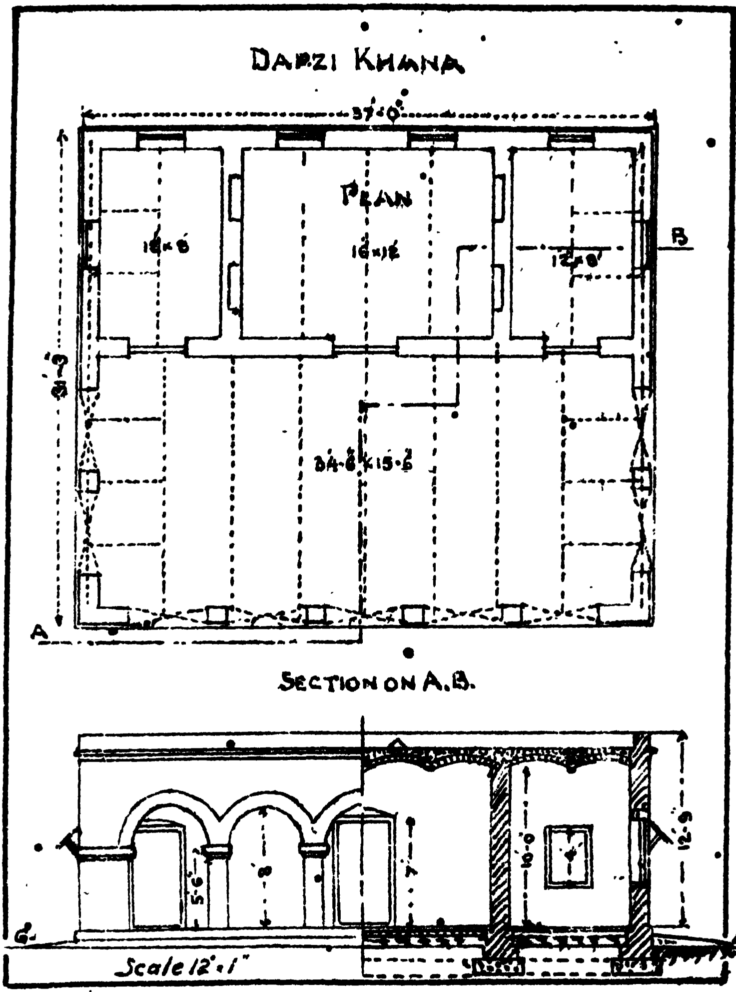
Scale 30'·1"

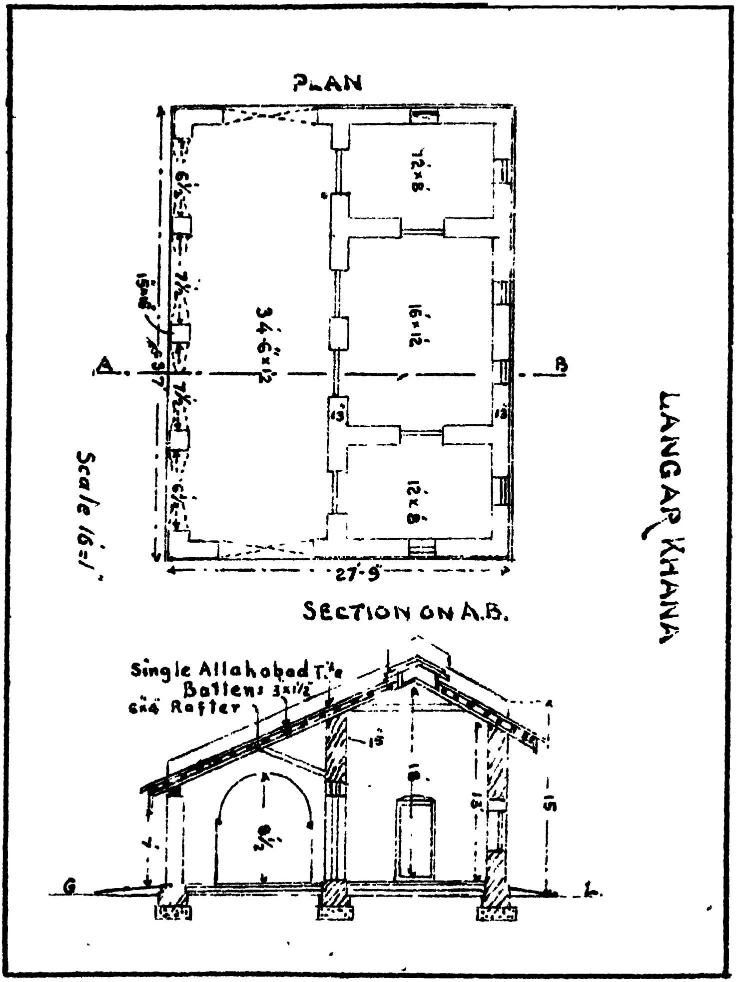



DETAIL OF RECORD RACK
Scale 5-1
SECTION ON A.A
BATTEN 2×1½
L. IRON 1½×1½×¼
DETAIL OF BASE OF CAST IRON
Scale 5-1
CAST IRON COLUMN
CONCRETE
WOODEN BARS 2×3"
IRON BAR
FLOOR
CONCRETE
STONE SLAB

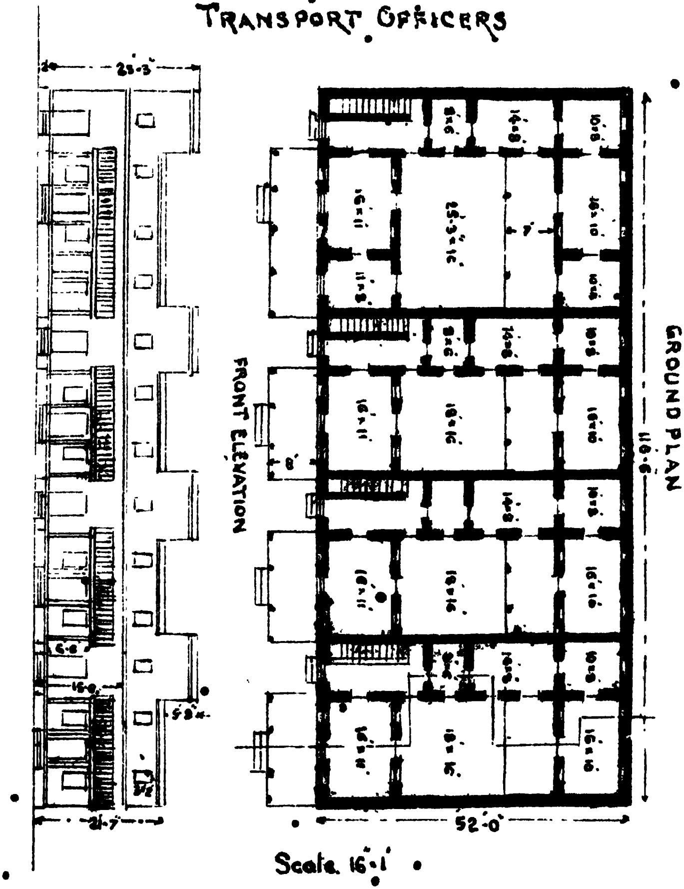

STANDARD PLAN WOODEN RECORD RACK SCALE 1.2.3 FIG: 5'=1"
FIG 1
PLAN OF SINGLE RACKS NEAR WALL
GALLERY
1/2" TIE BOLT
INTERMEDIATE
END BAY
FILLING PIECES
FIG 4
PLAN OF RACKS LAID ACROSS ROOMS FROM WALL TO WALL
Scale 10'=1"
WALL
EACH
END BAY
INTERMEDIATE BAY.
FIG 2
FRONT ELEVATION ON C.D.
FIG 3
THE PORTION ABOVE THIS TO BE AS IN FIG 5 CROSS SECTION OF GALLERIES EXCEPT THAT THE R. FOR SINGLE RACKS NEAR WALLS RAILING & GALLARIES WILL BE AS SHOWN HERE
ON A.B. VIDE FIG 1
Hoop IRON
GALLERY HAND RAIL
GALLERY PLANK
1/2" BOLT
Battens
INTERMEDIATE BAY
END BAY
TIE BOLT
BRICK
STONE
THICK PLATE
Stone


STANDARD PLAN WOODEN RECORD RACKS
FIG. 5
CROSS SECTION OF GALLERIES FOR RACKS LAID ACROSS ROOMS FROM WALL TO WALL (ON E.F.
WALL
22-1/4
FIG. 6
CROSS SECTION OF GALLERIES FOR SINGLE RACKS
FIG. 8
DETAIL AT J.
BATTENS
FIG. 7
PLAN OF GALLERIES FOR SINGLE RACKS
FIG. 10
PLAN
DETAIL
1/2 THICK PLATE
PLATE

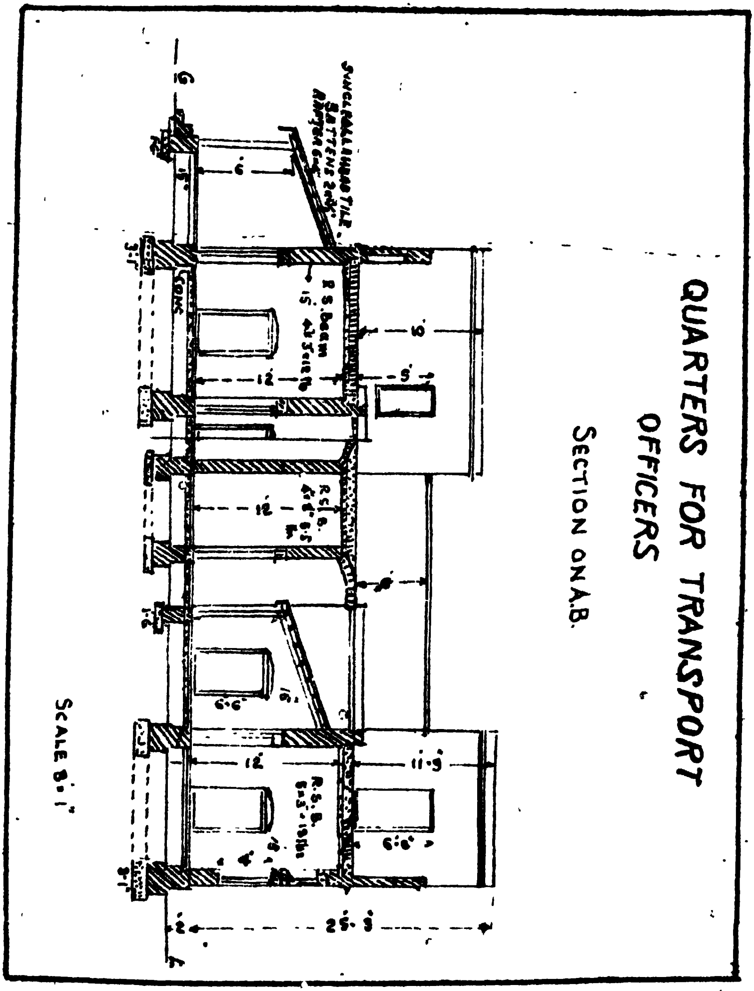

DARZI KHANA
37'-0"
PLAN
16×8
16×12
12×8
34·6×15·6
A
B
SECTION ON A.B.
Scale 12'=1"

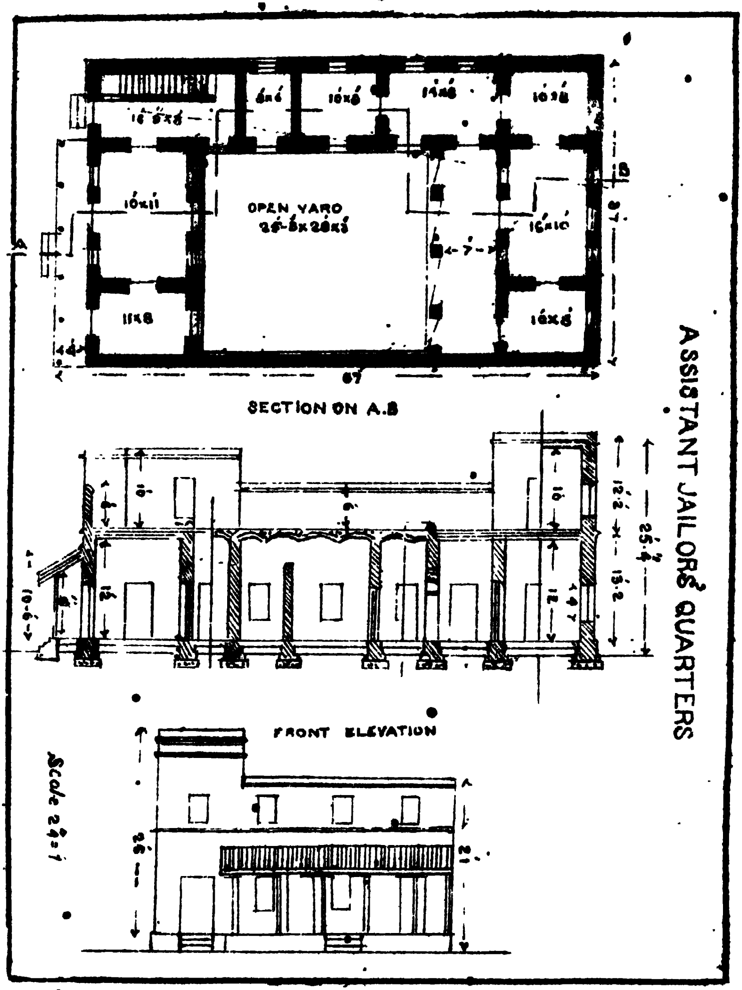

PLAN
34'-6"x12'
12'x8'
16'x12'
12'x8'
27'-9"
A
B
Scale 16'=1"
LANGAR KHANA
SECTION ON A.B.
Single Allahabad Tile
Battens 3"x1½"
6"x4" Rafter
G
L

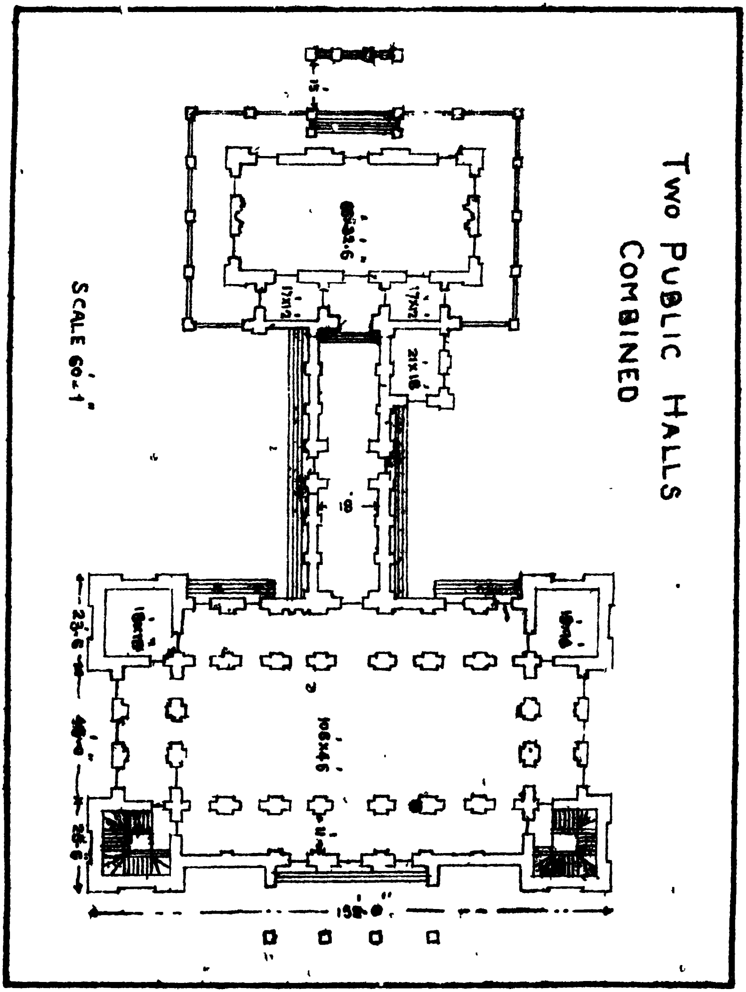
QUARTERS FOR TRANSPORT OFFICERS

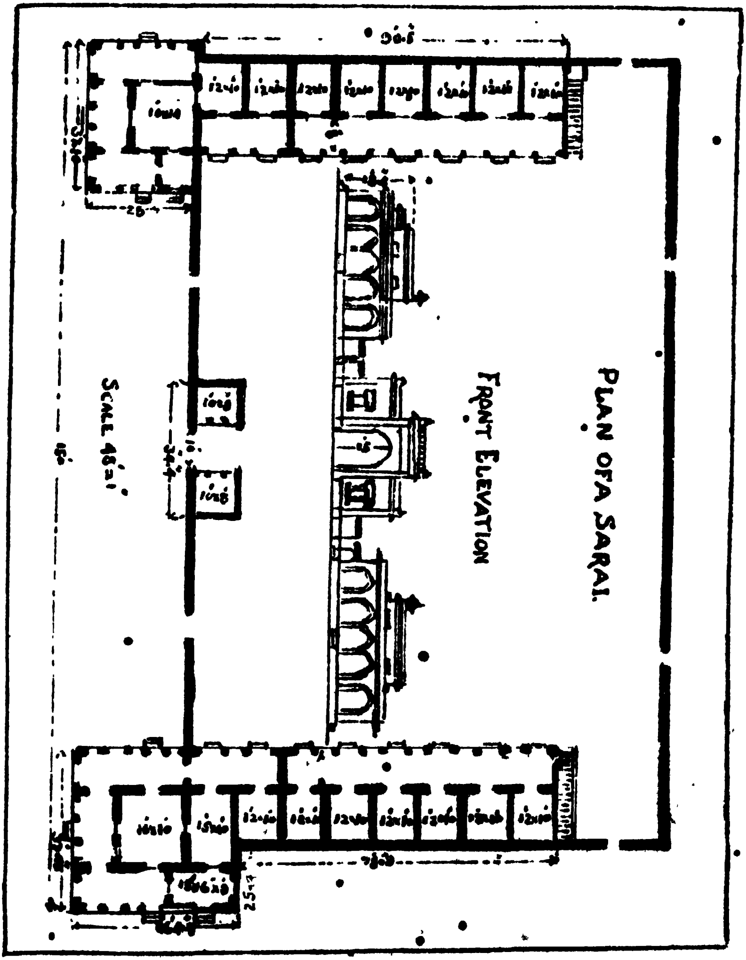


Scale. 16"=1'

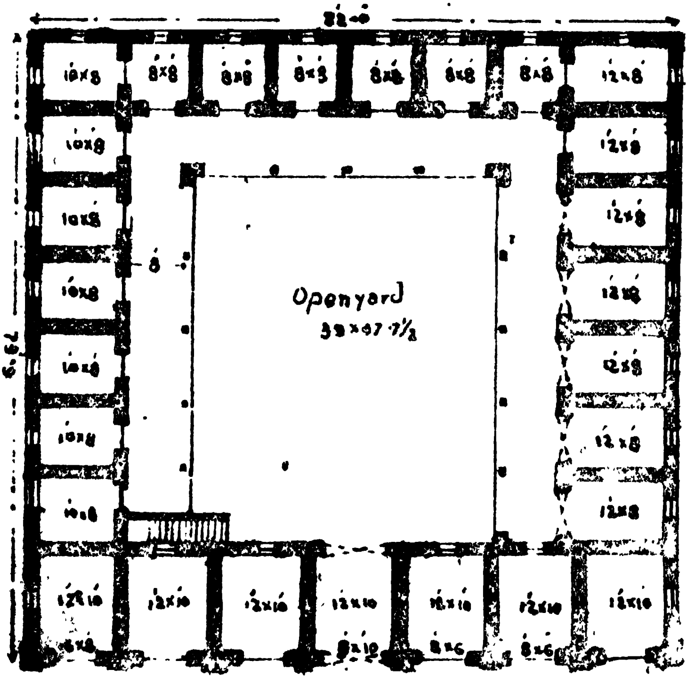

QUARTERS FOR TRANSPORT
OFFICERS
SECTION ON A.B.
SCALE 8'=1"


ASSISTANT JAILORS' QUARTERS
OPEN YARD
SECTION ON A.B
FRONT ELEVATION
Scale 24=1

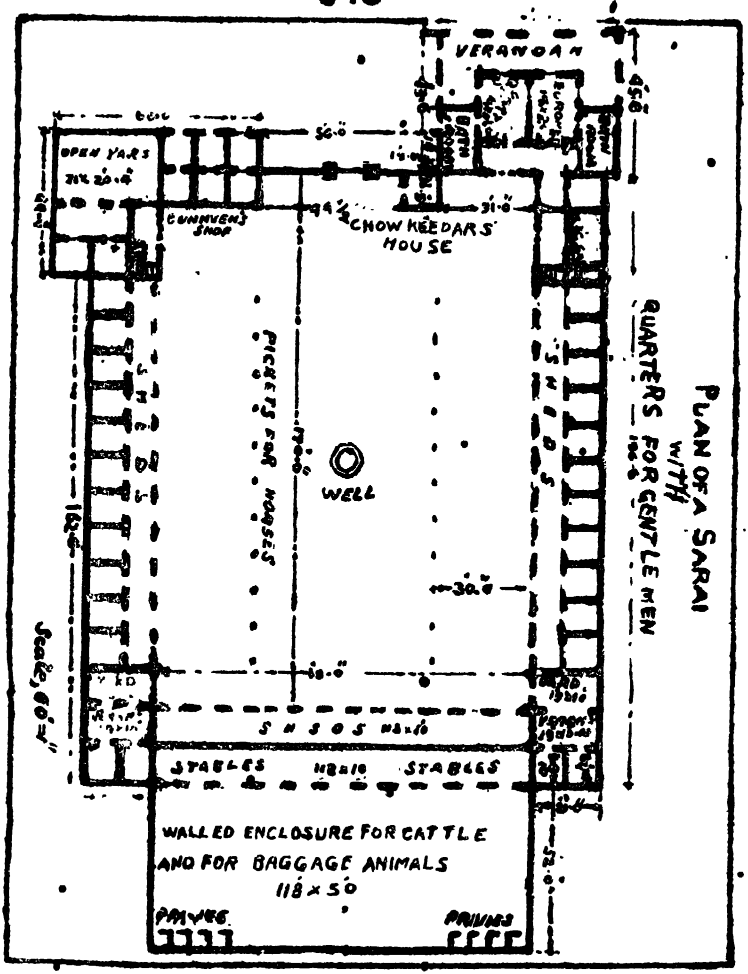

TWO PUBLIC HALLS COMBINED
SCALE 60'-1"


PLAN OF A SARAI.
FRONT ELEVATION
SCALE 48 = 1

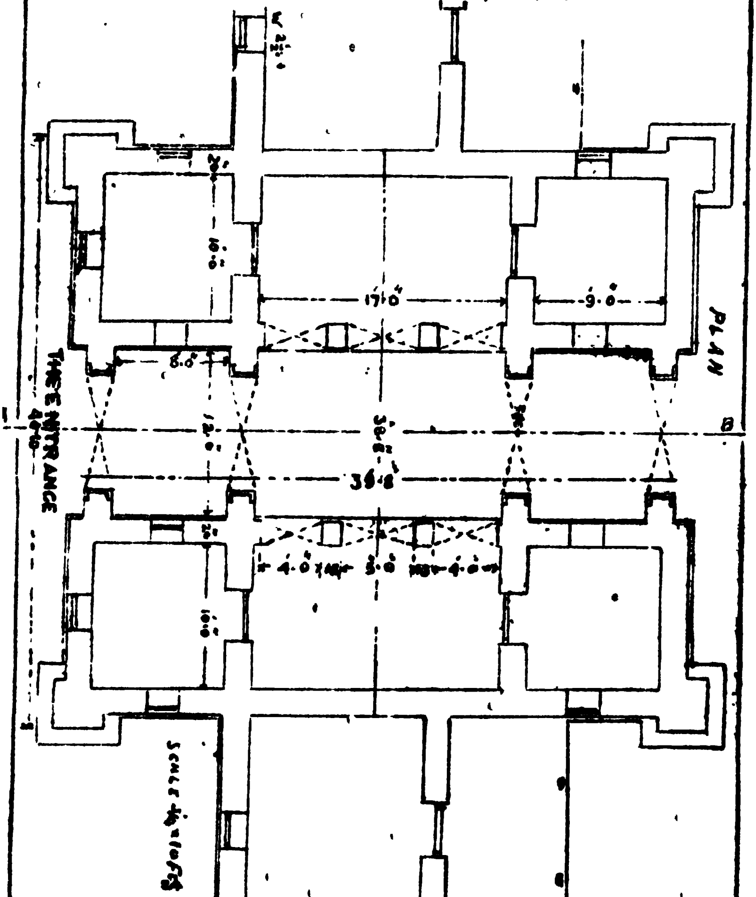
PLAN OF A SARAI



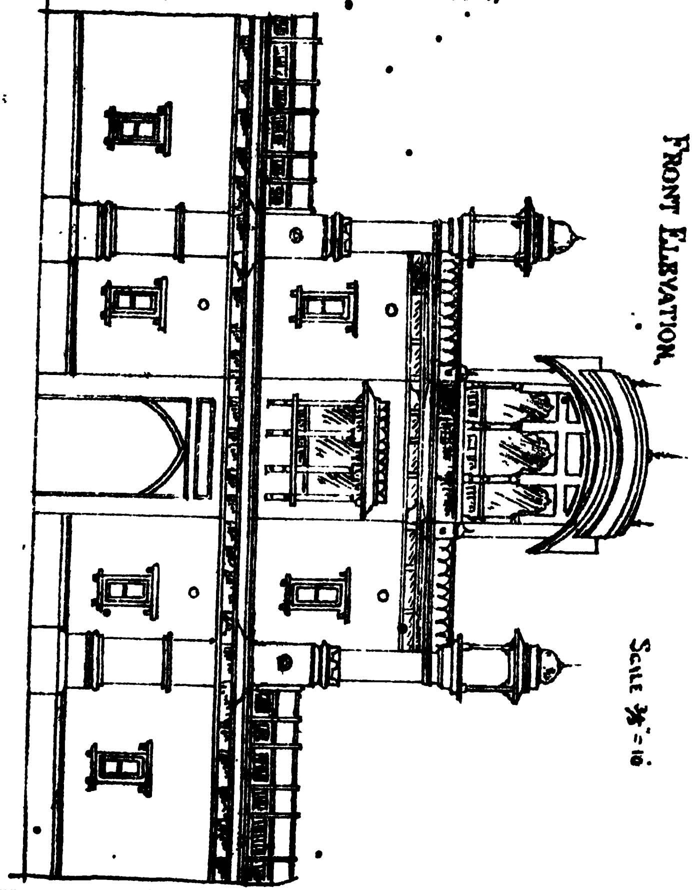
Scale 24=1


PLAN OF A SARAI WITH QUARTERS FOR GENTLE MEN
VERANDAH
OPEN YARD
BUNNIA'S SHOP
CHOWKEEDAR'S HOUSE
PICKETS FOR HORSES
WELL
SHEDS
STABLES
WALLED ENCLOSURE FOR CATTLE AND FOR BAGGAGE ANIMALS 118 x 50
PRIVIES
Scale, 60'=1"

DESIGN OF A SARAI GATE



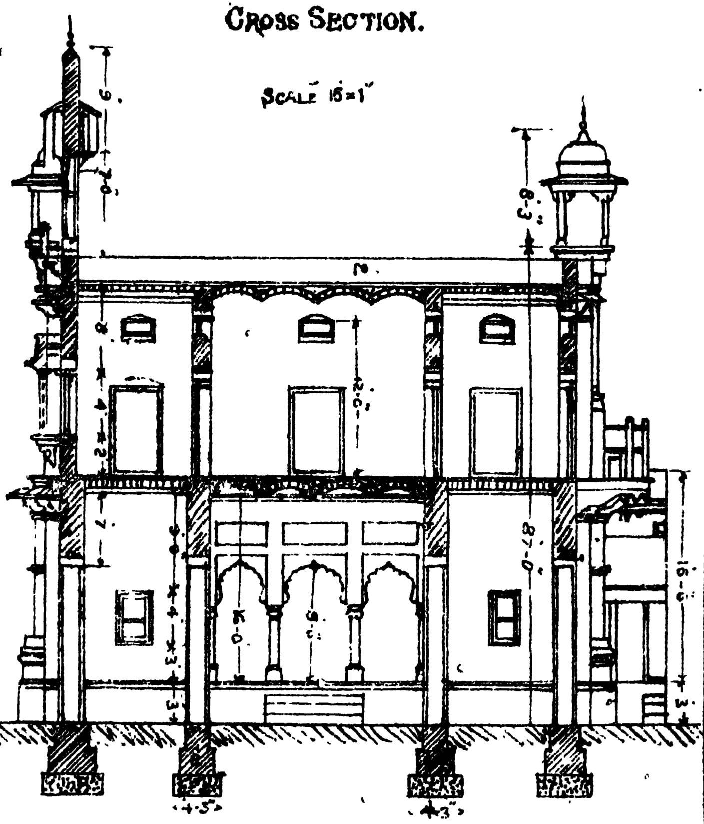
(SARAI GATE CONTINUED.)

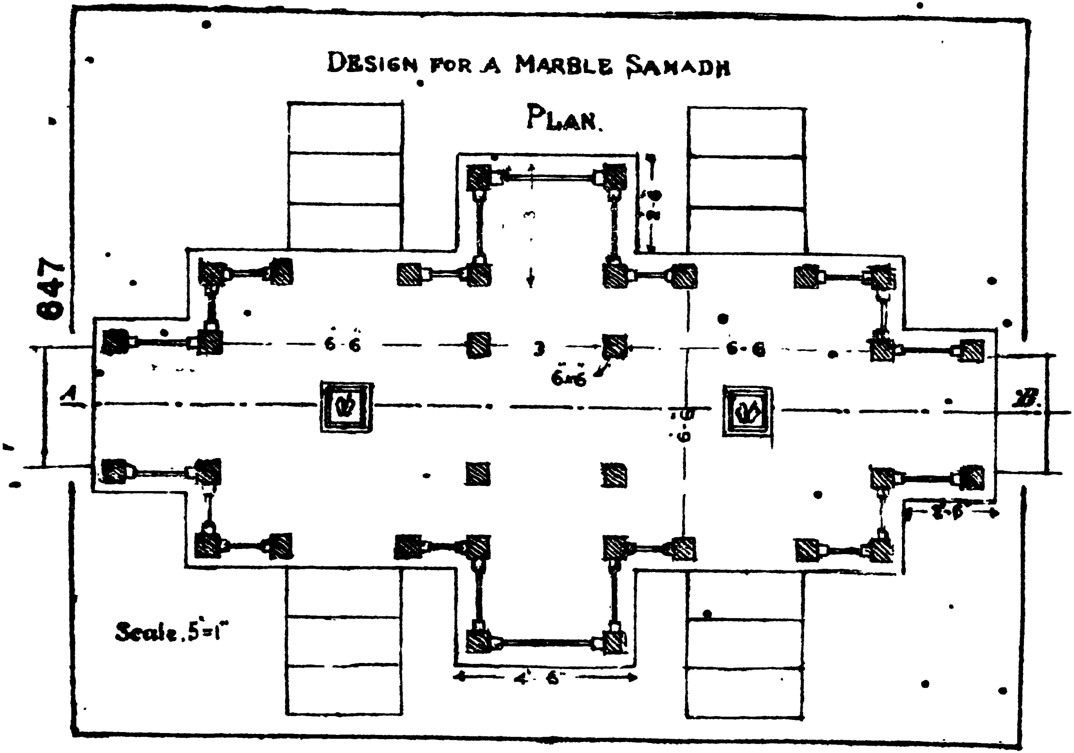


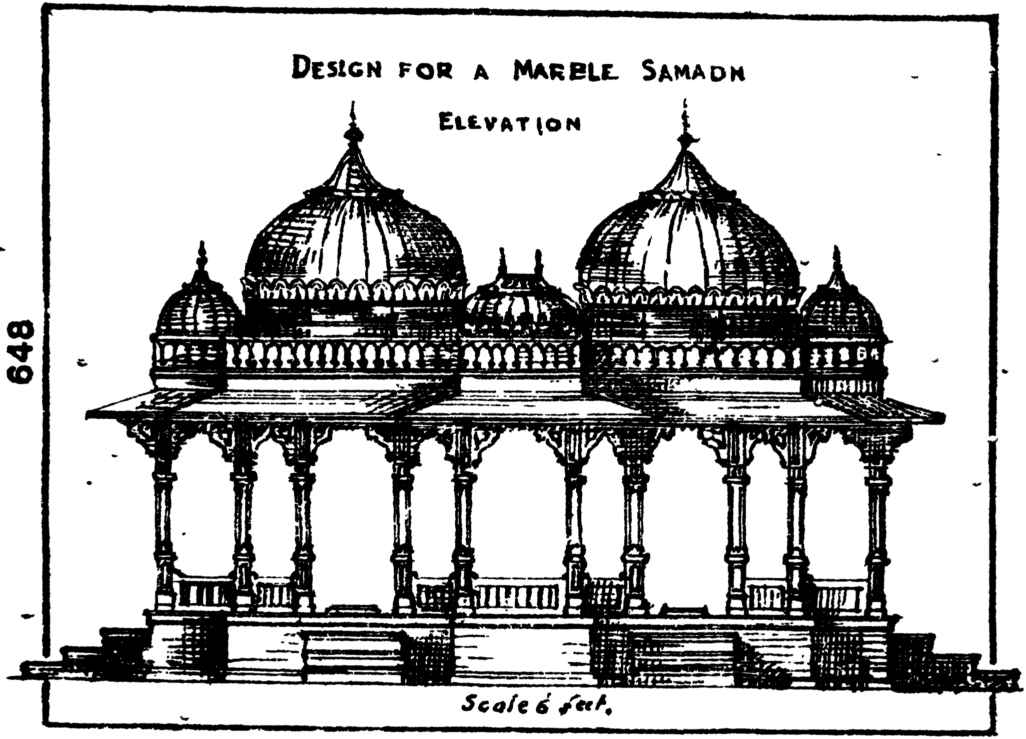
SARAI GATE, CONTINUED.

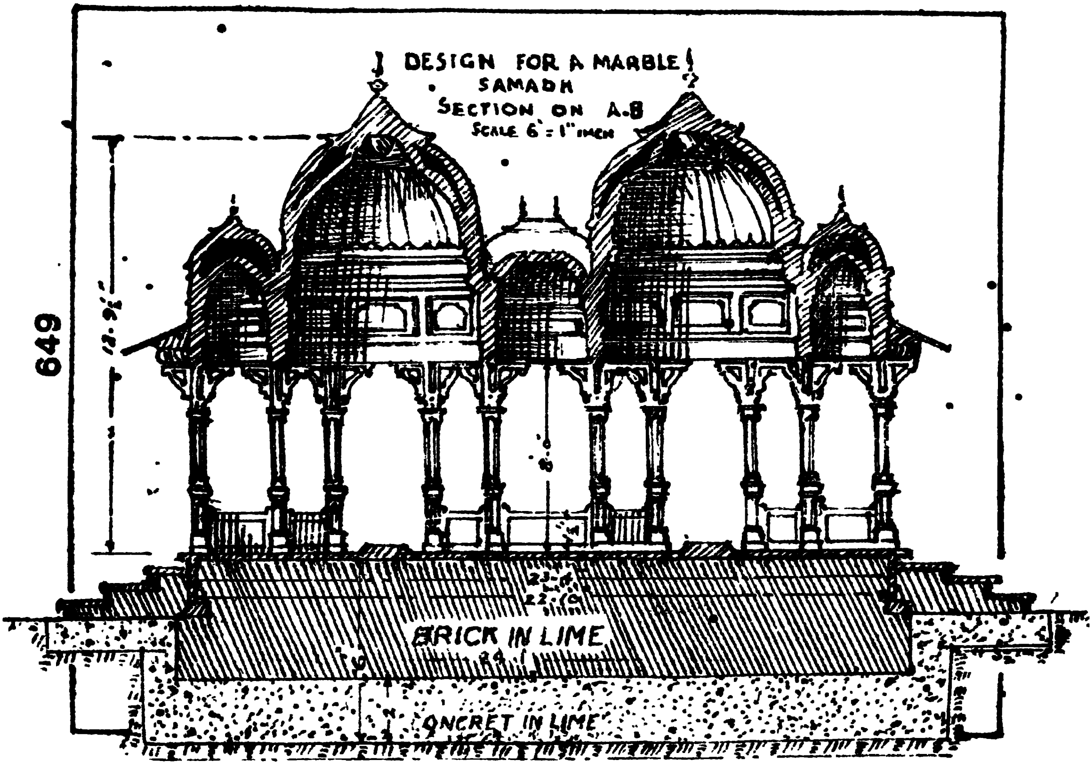
CROSS SECTION.

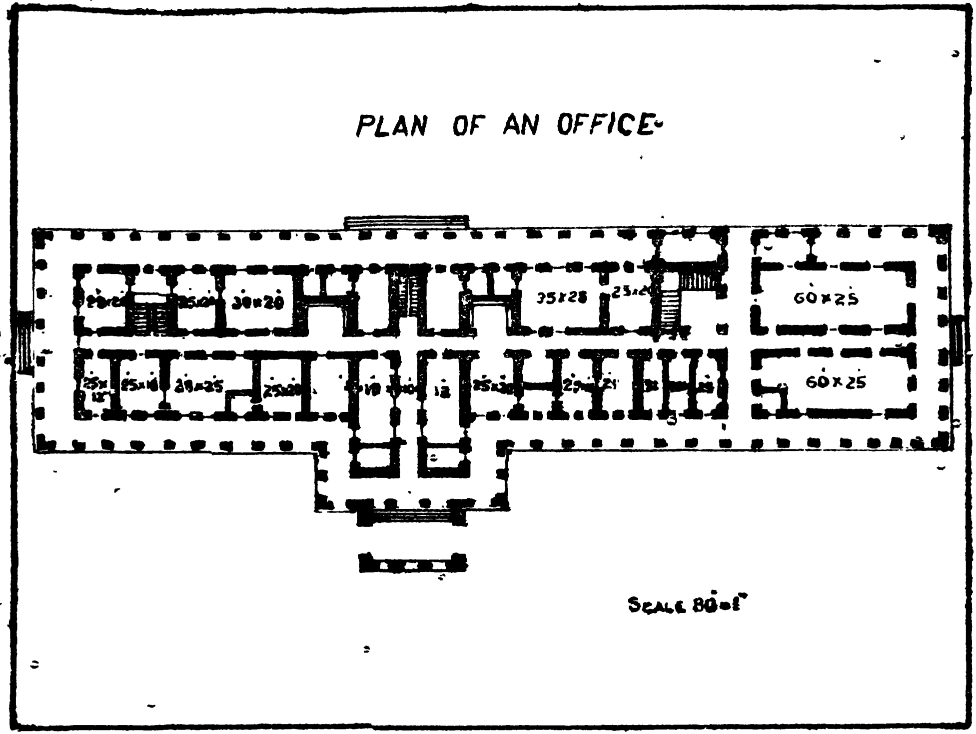
SCALE 15'=1"



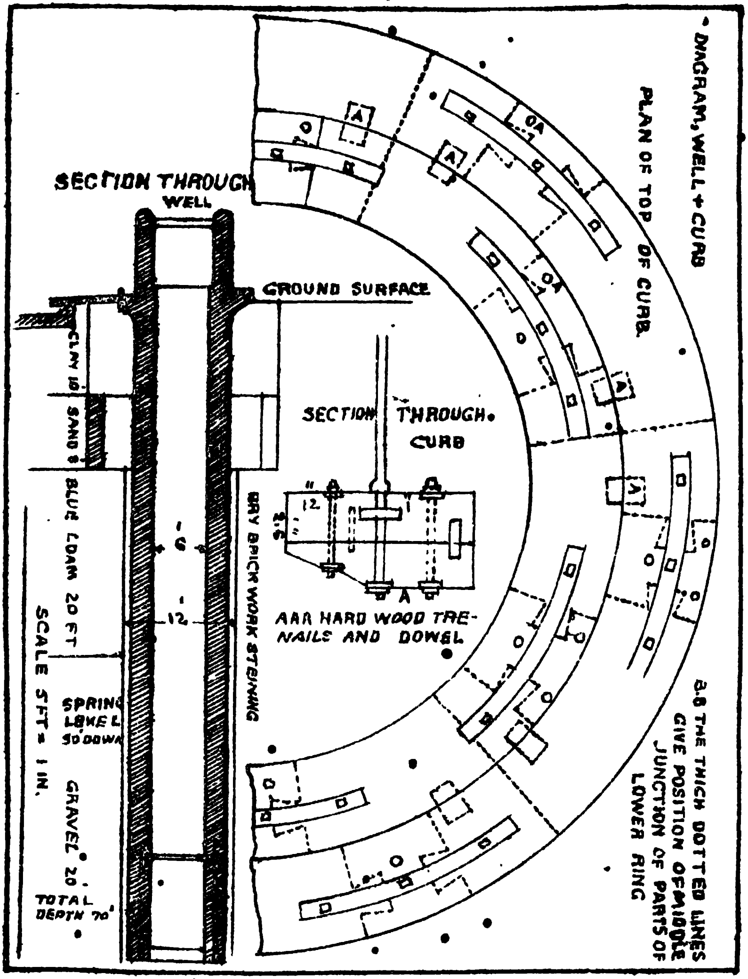

DESIGN FOR A MARBLE SAMADH
PLAN.
Scale. 5'=1"
6-6
3
6-6
6-6
6-6
4'-6"
2-6
A
B.


DESIGN FOR A MARBLE SAMADH
ELEVATION
Scale 6 feet.

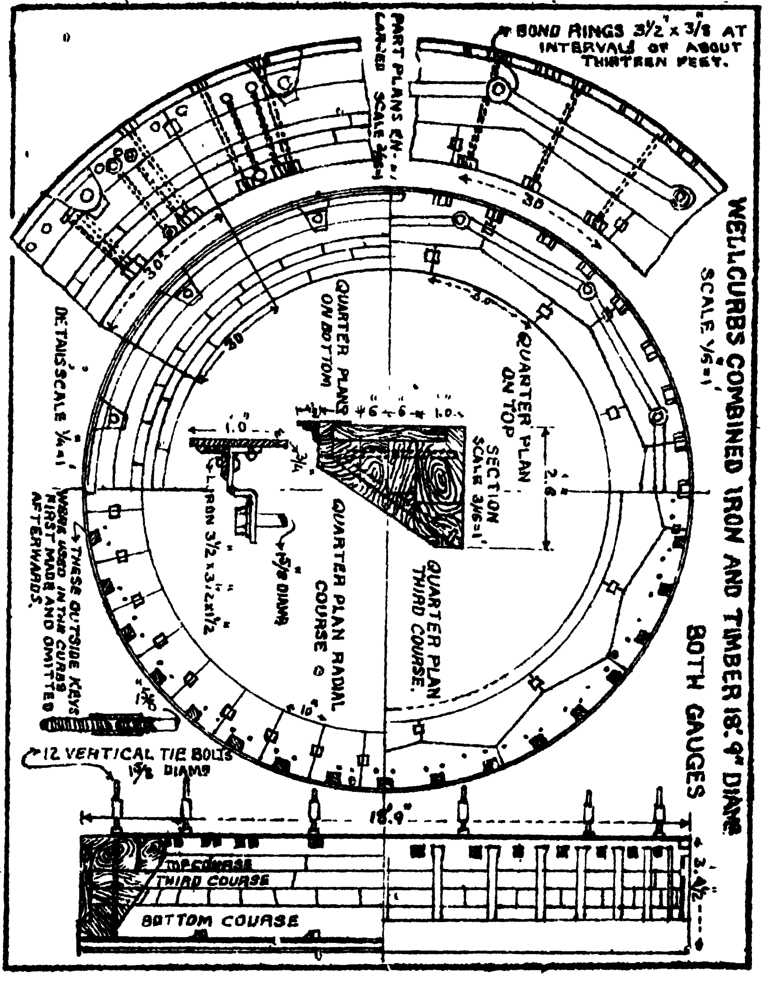

DESIGN FOR A MARBLE
SAMADH
SECTION ON A.B
SCALE 6' = 1" INCH
BRICK IN LIME
CONCRET IN LIME

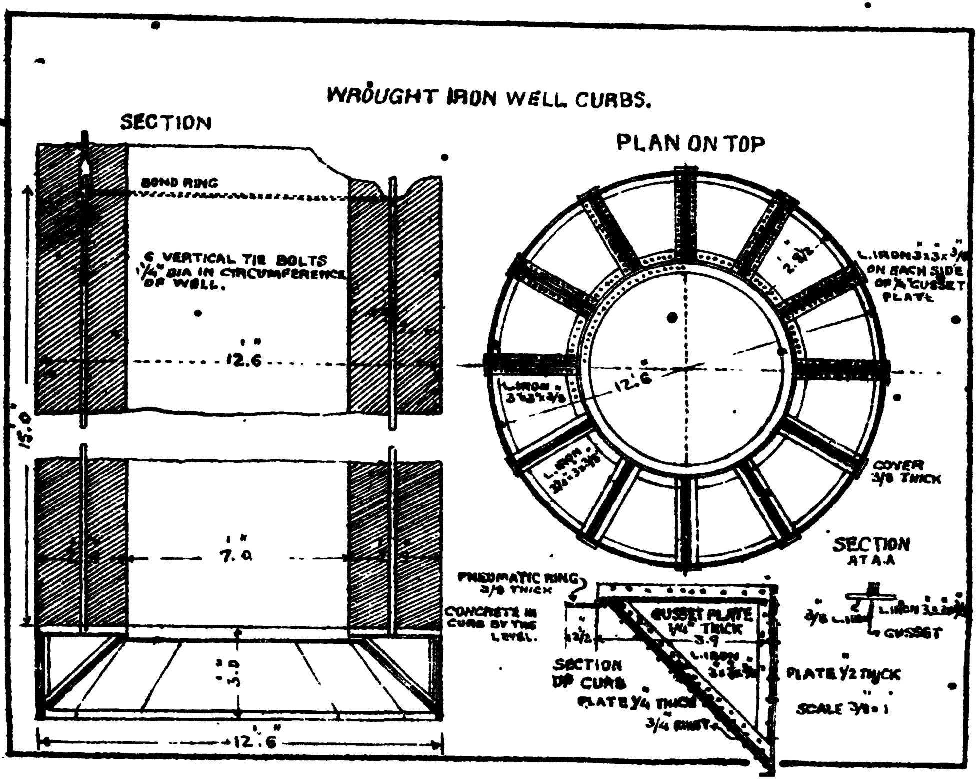

PLAN OF AN OFFICE.
30x20
35x28
60x25
60x25
Scale 80=1"

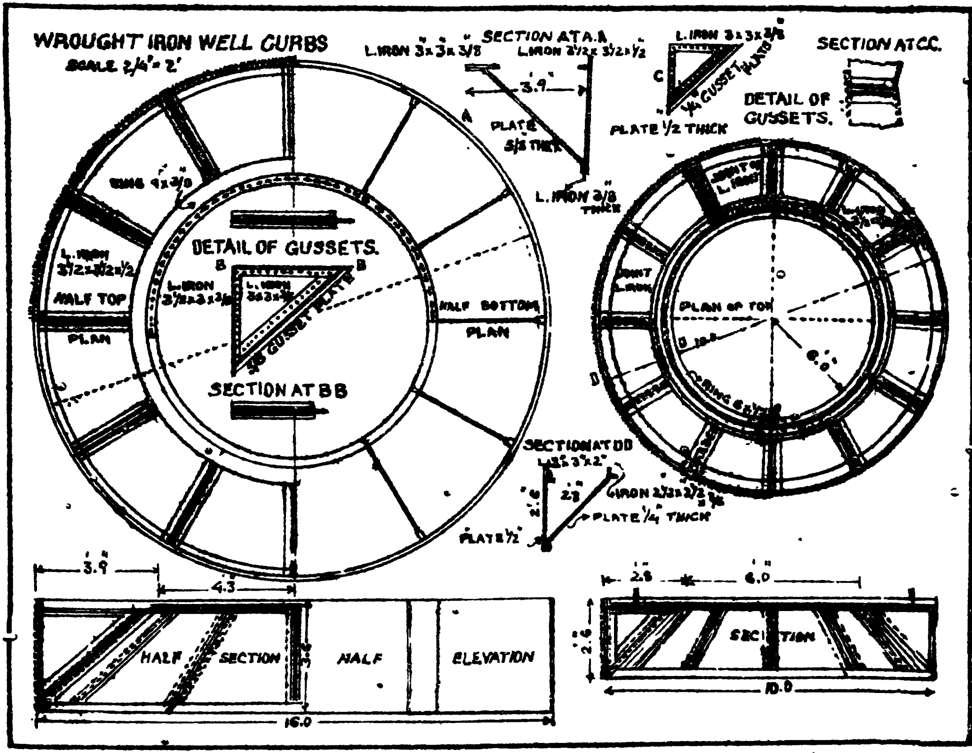
651


DIAGRAM, WELL + CURB
PLAN OF TOP OF CURB
SECTION THROUGH WELL
GROUND SURFACE
SECTION THROUGH CURB
AAR HARD WOOD TRE-NAILS AND DOWEL
DRY BRICK WORK STEINING
CLAY 10
SAND 8
BLUE LOAM 20 FT
SPRING LEVEL 50' DOWN
GRAVEL 20
TOTAL DEPTH 70'
SCALE 5FT = 1 IN.
THE THICK DOTTED LINES GIVE POSITION OF MIDDLE JUNCTION OF PARTS OF LOWER RING

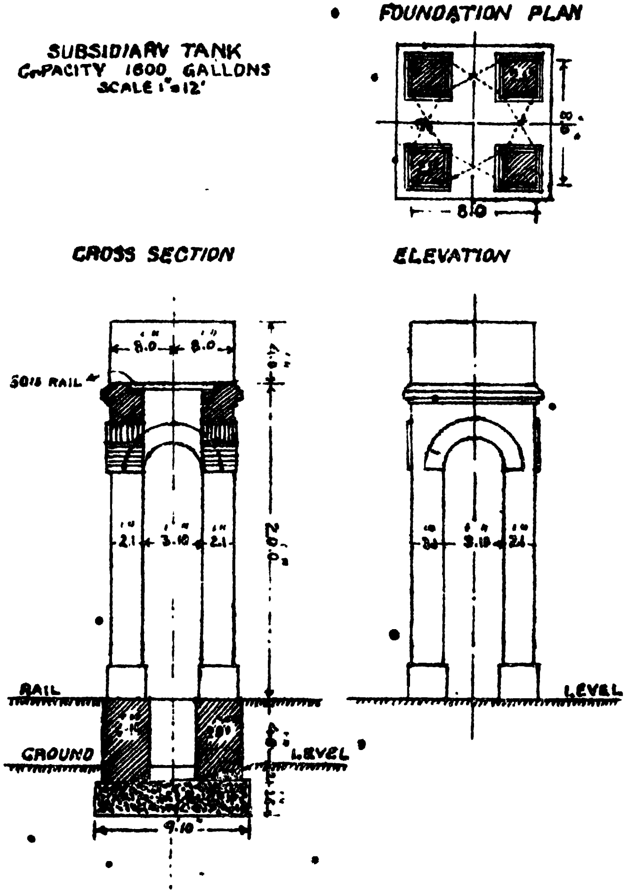
652

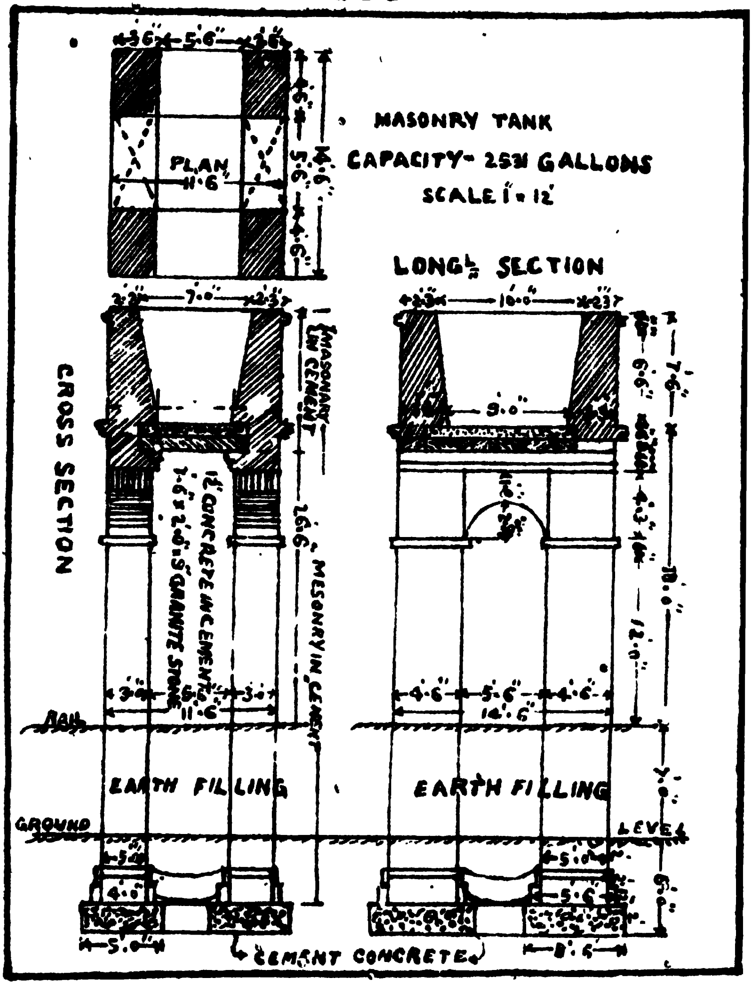

WELLCURBS COMBINED IRON AND TIMBER 18'.9" DIAM.
SCALE 1/6"=1'
BOTH GAUGES
BOND RINGS 3½" x 3/8" AT INTERVALS OF ABOUT THIRTEEN FEET.
PART PLANS EN-LARGED SCALE 3/16"=1'
QUARTER PLAN ON BOTTOM
QUARTER PLAN ON TOP
SECTION SCALE 3/16"=1'
QUARTER PLAN RADIAL COURSE
QUARTER PLAN THIRD COURSE.
L IRON 3½ x 3½ x ½
5/8" DIAM.
DETAILS SCALE 1/4"=1'
THESE OUTSIDE KEYS WERE USED IN THE CURBS FIRST MADE AND OMITTED AFTERWARDS.
12 VERTICAL TIE BOLTS 1⅛" DIAM.
18'.9"
TOP COURSE
THIRD COURSE
BOTTOM COURSE

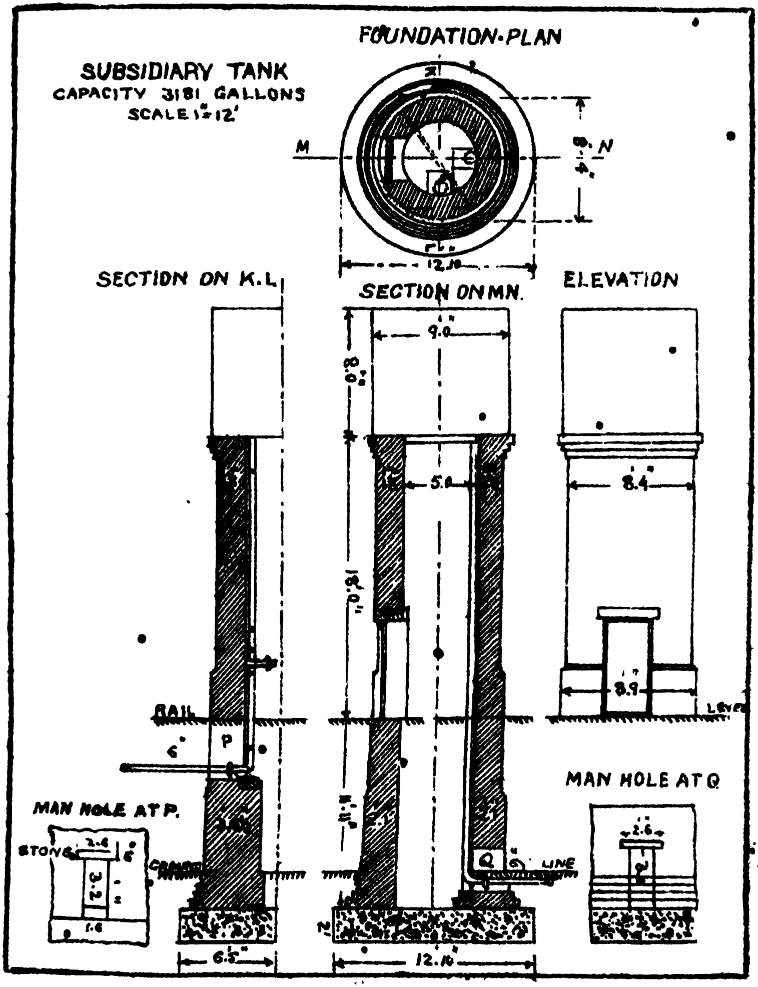

WROUGHT IRON WELL CURBS.
SECTION
BOND RING
6 VERTICAL TIE BOLTS 1/4" DIA IN CIRCUMFERENCE OF WELL.
12.6
15.0
7.0
3.0
12.6
PLAN ON TOP
L IRON 3x3x3/8 ON EACH SIDE OF 1/4" GUSSET PLATE
12.6
COVER 3/8 THICK
SECTION AT A.A
PNEUMATIC RING 3/8 THICK
CONCRETE IN CURB BY THE LEVEL.
GUSSET PLATE 1/4" THICK
3.9
SECTION OF CURB
PLATE 1/4 THICK
3/4 RIVETS
PLATE 1/2 THICK
GUSSET
SCALE 3/8=1

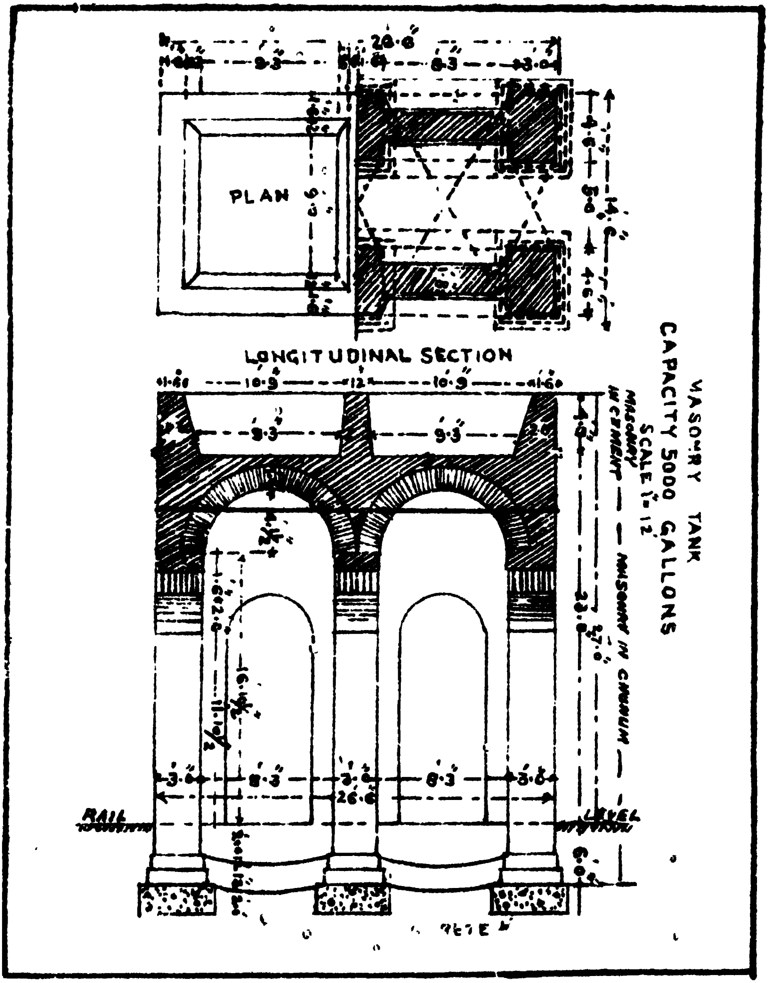

WROUGHT IRON WELL CURBS
SCALE 2/4" = 2'
SECTION AT A.A
L. IRON 3 x 3 x 3/8
L. IRON 2 1/2 x 3 1/2 x 1/2
3.9
A
PLATE 5/8 THICK
L. IRON 3/8 THICK
L. IRON 3 x 3 x 3/8
C
1/4" GUSSET PLATE
PLATE 1/2 THICK
DETAIL OF GUSSETS.
SECTION AT C.C.
DETAIL OF GUSSETS.
B
B
L. IRON 3 1/2 x 3 1/2 x 1/2
L. IRON 3 x 3 x 3/8
3/8 GUSSET PLATE
SECTION AT BB
HALF TOP
PLAN
HALF BOTTOM
PLAN
PLAN OF TOP
D
SECTION AT DD
PLATE 1/4" THICK
PLATE 1/2"
2.8
6.0
6.0
3.9
4.3
HALF SECTION
HALF ELEVATION
16.0
2.6
SECTION
10.0

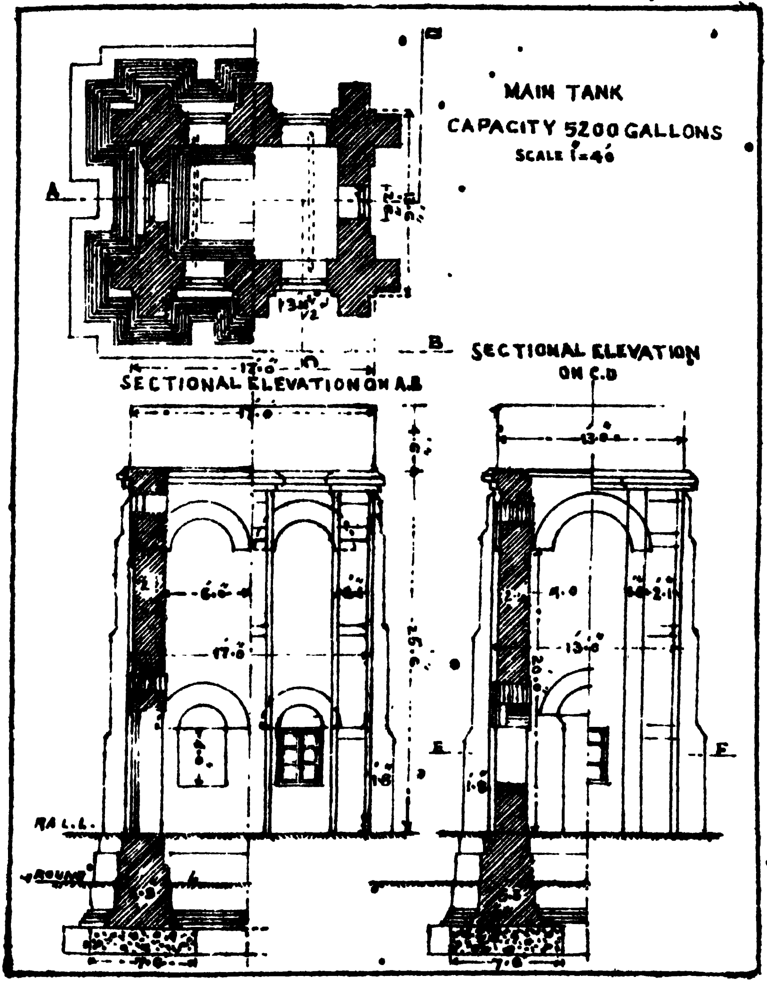
WATER TANKS

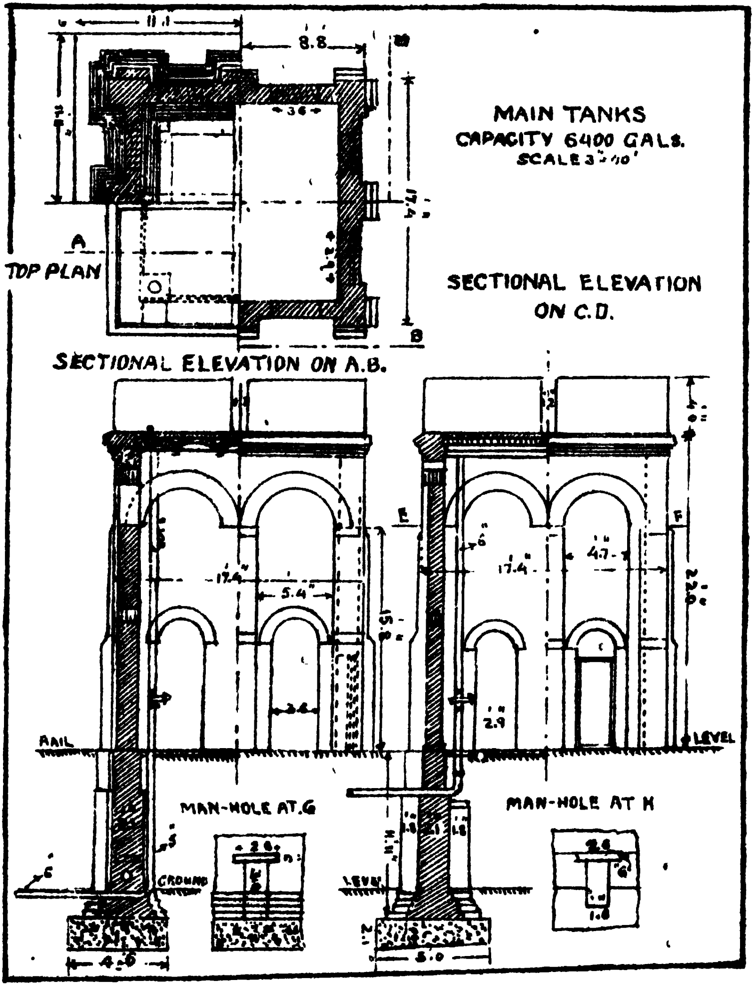

SUBSIDIARY TANK
CAPACITY 1600 GALLONS
SCALE 1" = 12'
FOUNDATION PLAN
8.0
CROSS SECTION
ELEVATION
50lb RAIL
8.0
8.0
4.0
20.0
2.1
3.10
2.1
RAIL
LEVEL
GROUND
LEVEL
9.10

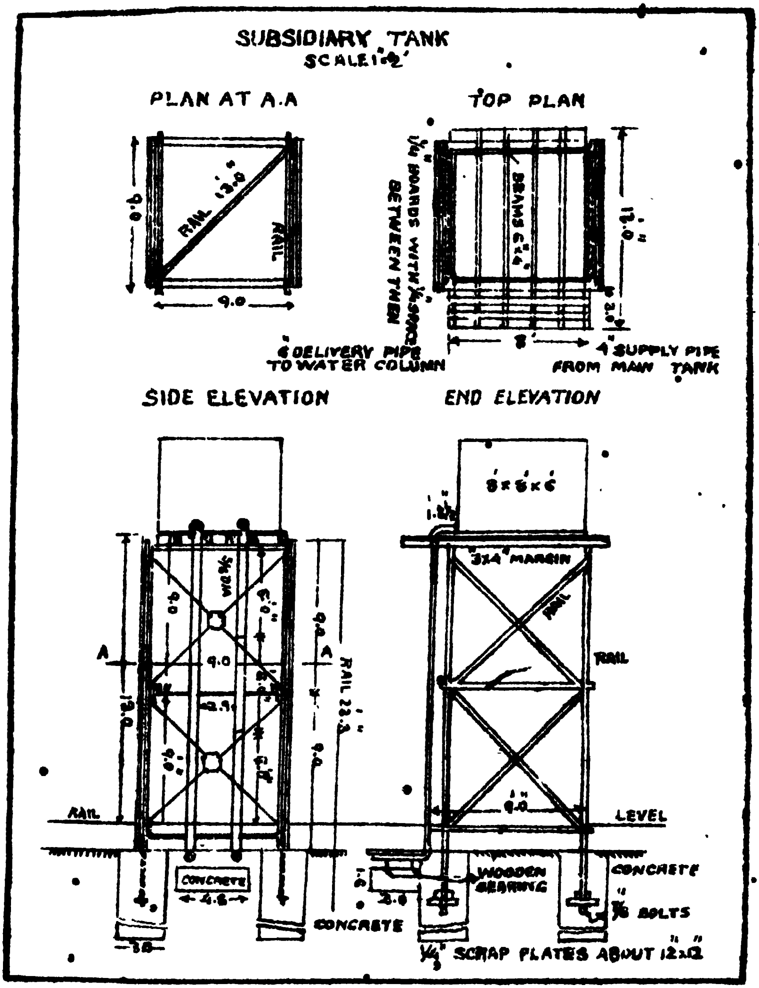

MASONRY TANK
CAPACITY- 2531 GALLONS
SCALE 1" = 12'
PLAN
LONGL. SECTION
CROSS SECTION
MASONRY IN CEMENT
12" CONCRETE IN CEMENT
7'·6" x 2'·0" x 15" GRANITE STONE
MESONRY IN CEMENT
RAIL
EARTH FILLING
GROUND
LEVEL
CEMENT CONCRETE

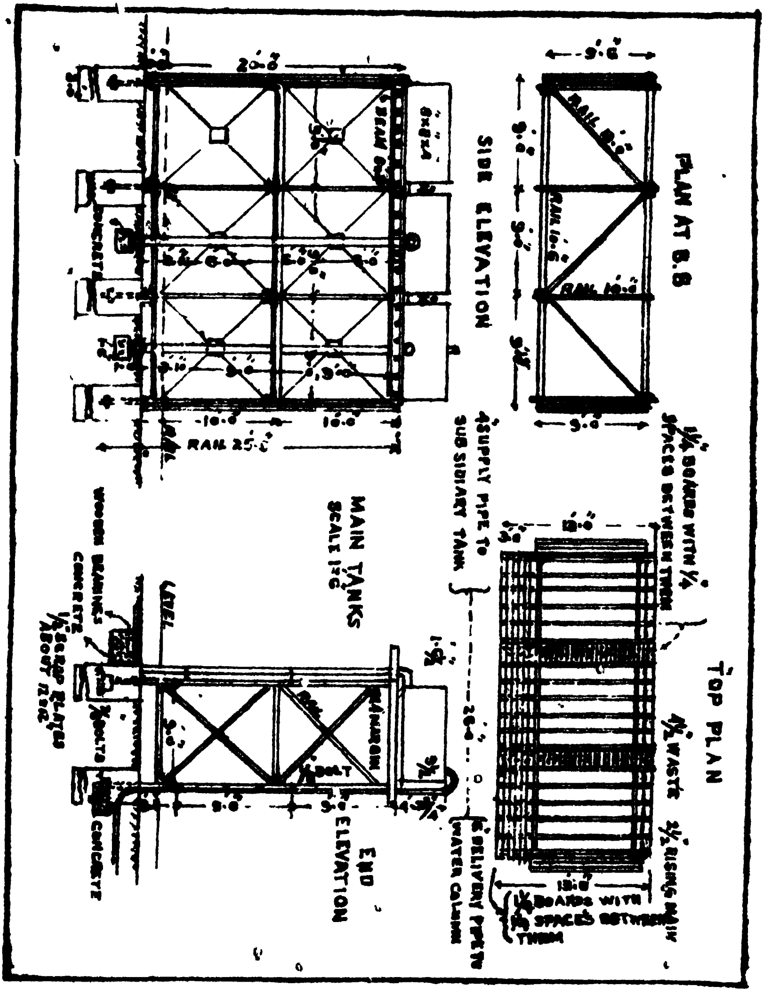

SUBSIDIARY TANK
CAPACITY 3181 GALLONS
SCALE 1"=12'
FOUNDATION·PLAN
M
N
12.10"
SECTION ON K.L
SECTION ON MN.
ELEVATION
9.0"
8.0"
5.0
8.4"
18.0"
8.9"
RAIL
P
6"
Q
LINE
MAN HOLE AT P.
MAN HOLE AT Q
2.6
6.5"
12.10"

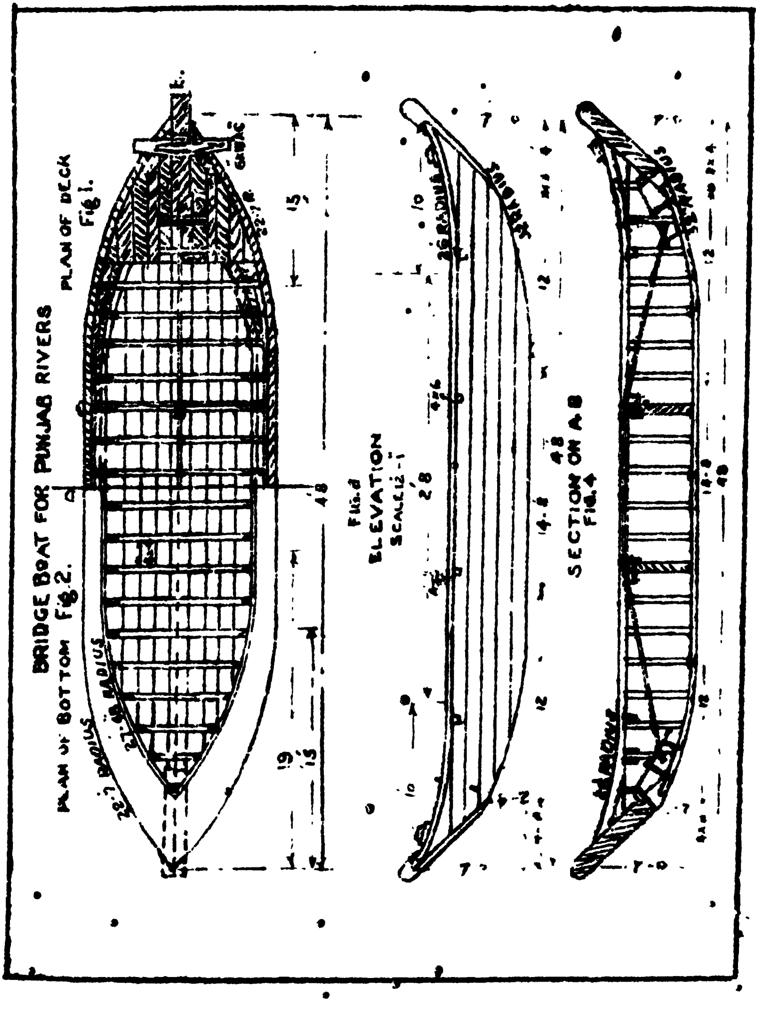

PLAN
LONGITUDINAL SECTION
MASONRY TANK
CAPACITY 5000 GALLONS
SCALE 1"=12'
MASONRY IN CEMENT
MASONRY IN CHUNAM
RAIL
LEVEL

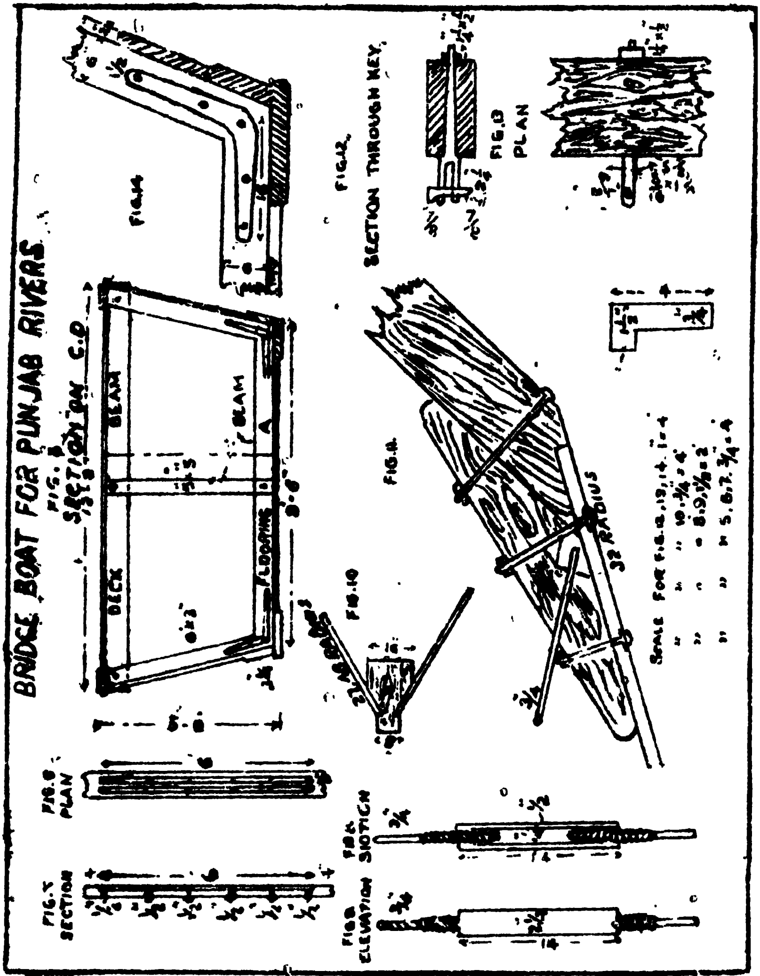

MAIN TANK
CAPACITY 5200 GALLONS
SCALE 1"=40'
SECTIONAL ELEVATION ON A.B
SECTIONAL ELEVATION ON C.D
A
B
E
F
17·0"
13·0"
6·0"
4·0

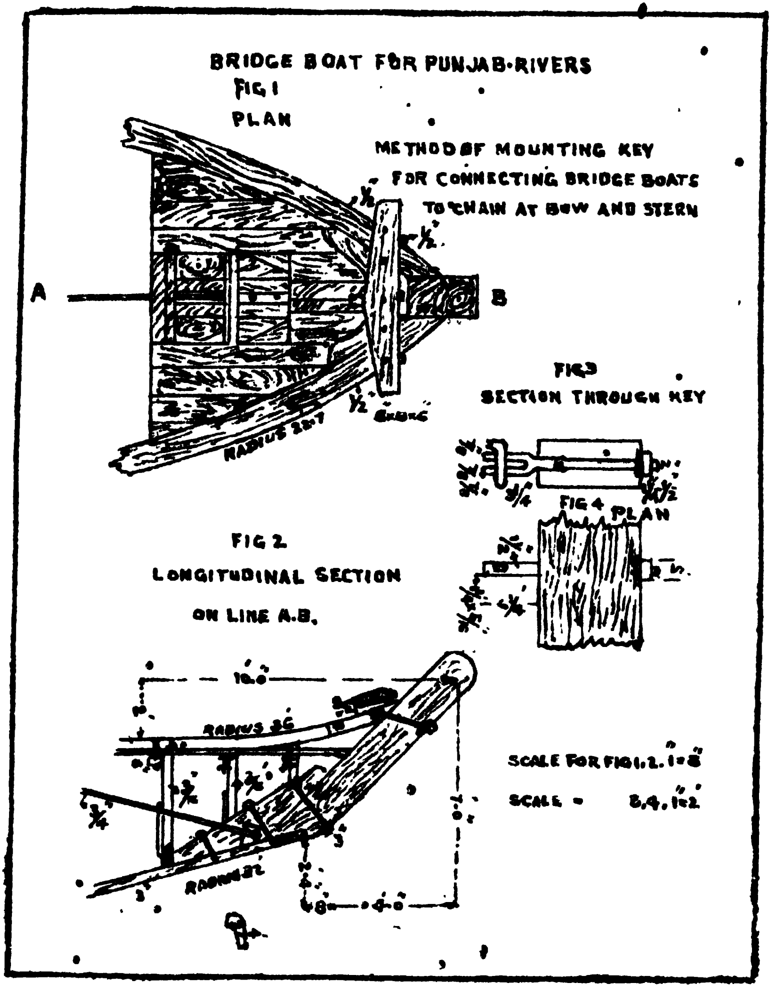

MAIN TANKS
CAPACITY 6400 GALS.
TOP PLAN
SECTIONAL ELEVATION ON C.D.
SECTIONAL ELEVATION ON A.B.
MAN-HOLE AT G
MAN-HOLE AT H
RAIL
LEVEL
GROUND
A
B
E
F
8.8
17.4
5.4
2.9
4.6
5.0

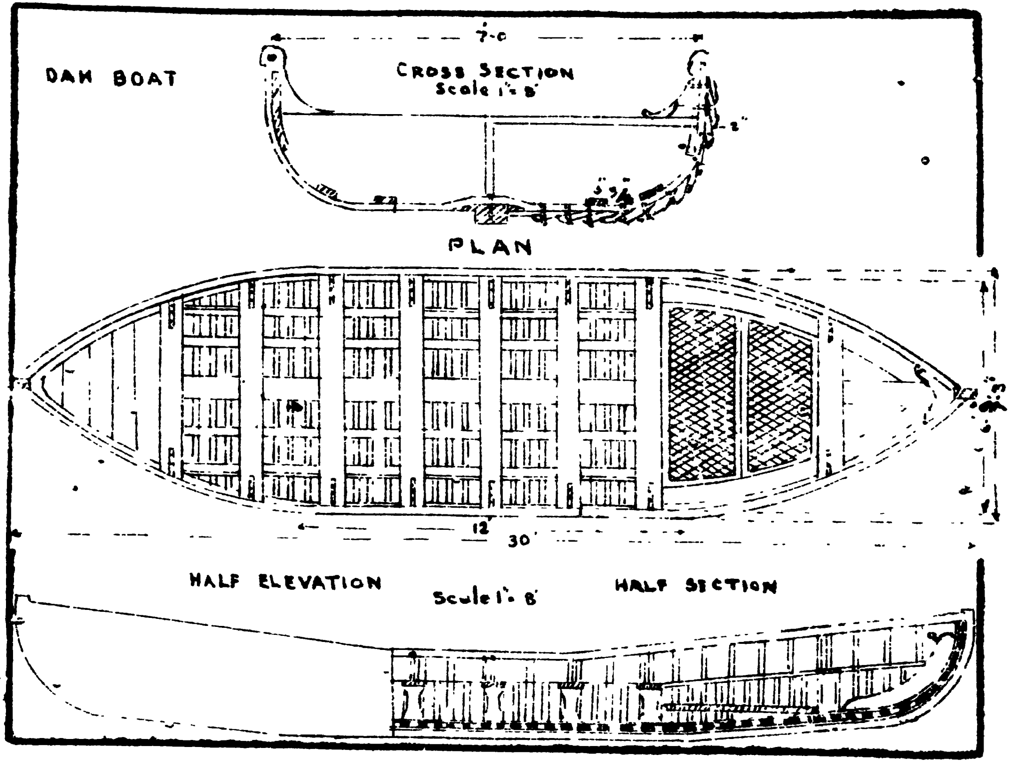

SUBSIDIARY TANK
SCALE 1/2"
PLAN AT A.A
RAIL 13.0"
RAIL
9.0
TOP PLAN
3/4" BOARDS WITH 1/4" SPACE BETWEEN THEM
BEAMS 6"x4"
13.0"
3.0"
8'
4" DELIVERY PIPE TO WATER COLUMN
4" SUPPLY PIPE FROM MAIN TANK
SIDE ELEVATION
END ELEVATION
8'x6'x6'
1.8"
3x4" MARGIN
RAIL
RAIL 23.3"
A
CONCRETE
4.6
3.6
LEVEL
WOODEN BEARING
CONCRETE
7/8" BOLTS
1/4" SCRAP PLATES ABOUT 12"x12"

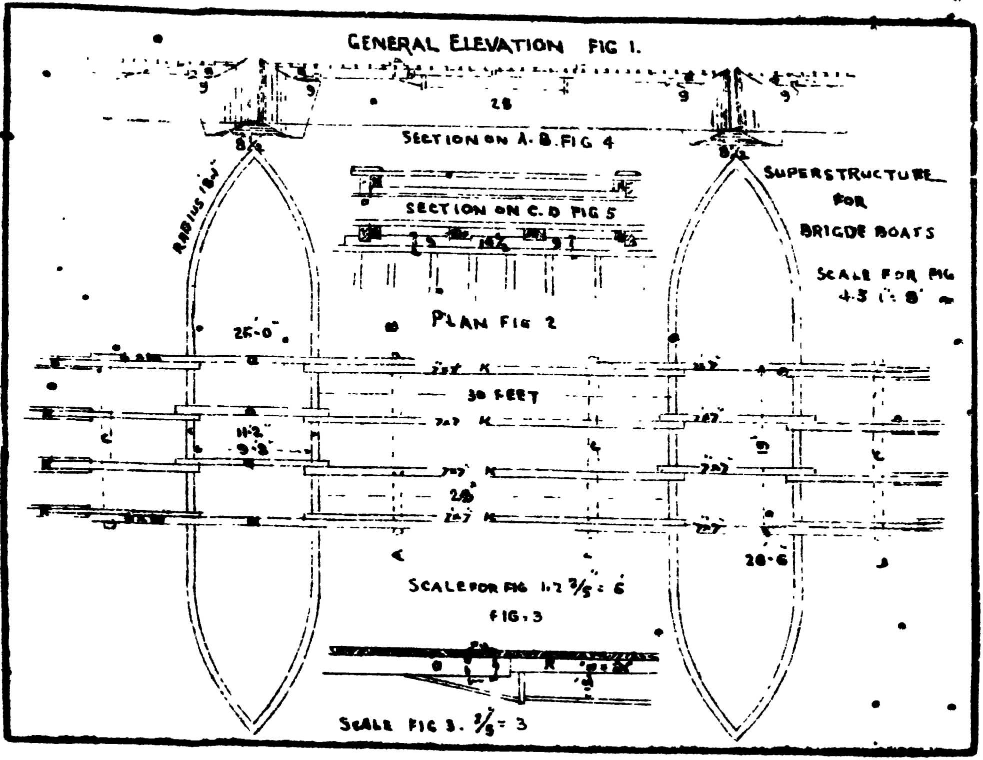

PLAN AT B.B
SIDE ELEVATION
TOP PLAN
MAIN TANKS
END ELEVATION
WATER COLUMN
CONCRETE

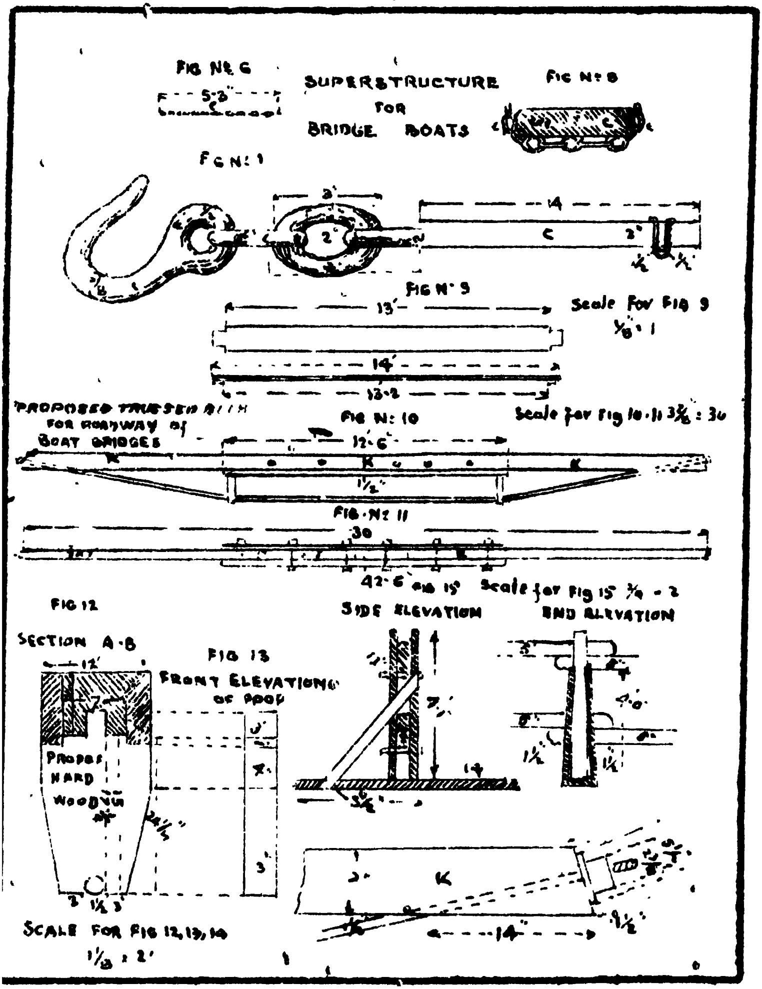

BRIDGE BOAT FOR PUNJAB RIVERS
PLAN OF DECK
Fig. 1.
PLAN OF BOTTOM
Fig. 2.
ELEVATION
SCALE 12-1
Fig. 3
SECTION ON A B
Fig. 4

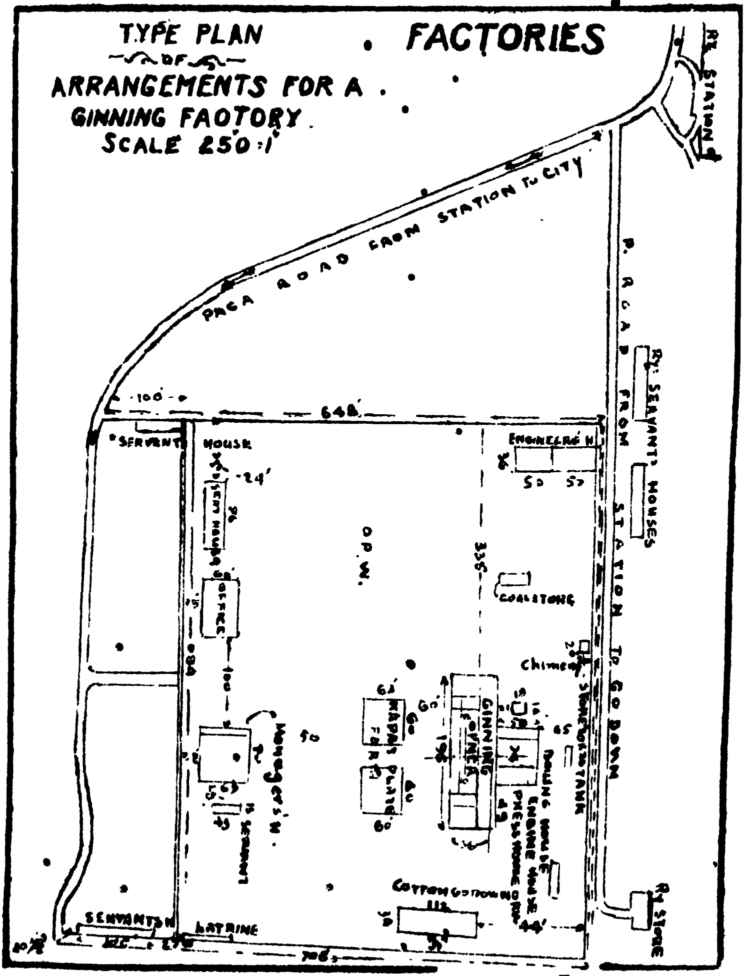

BRIDGE BOAT FOR PUNJAB RIVERS
FIG. 5
SECTION ON C.D
DECK
BEAM
FLOORING
FIG. 4
FIG. 2
SECTION THROUGH KEY
FIG. 3
PLAN
FIG. 10
32 RADIUS
FIG. 6
PLAN
FIG. 7
SECTION
ELEVATION

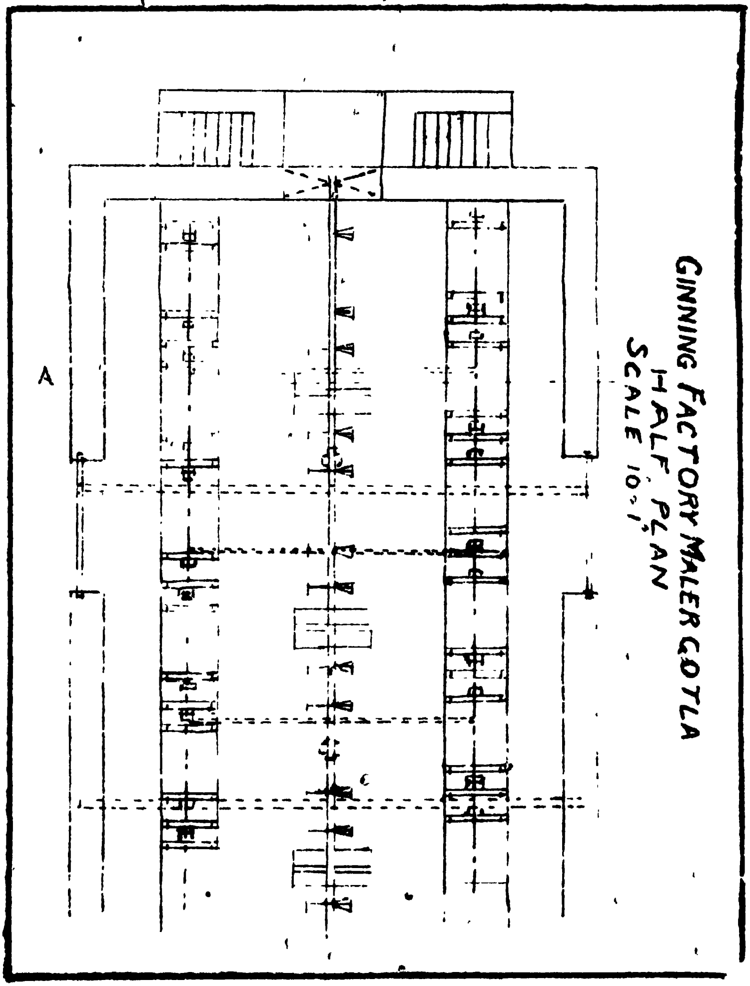

BRIDGE BOAT FOR PUNJAB RIVERS
FIG 1
PLAN
METHOD OF MOUNTING KEY
FOR CONNECTING BRIDGE BOATS
TO CHAIN AT BOW AND STERN
A
B
RADIUS 22.7
FIG 3
SECTION THROUGH KEY
FIG 4 PLAN
FIG 2
LONGITUDINAL SECTION
ON LINE A.B.
10.0
RADIUS 36
SCALE FOR FIG 1.2. 1=8
SCALE = 3.4. 1=2


DAM BOAT
7-0
CROSS SECTION
Scale 1" = 8'
2"
PLAN
12'
30'
HALF ELEVATION
Scale 1" = 8'
HALF SECTION


GENERAL ELEVATION FIG 1.
SECTION ON A. B. FIG 4
SECTION ON C. D FIG 5
PLAN FIG 2
SUPERSTRUCTURE FOR BRIGDE BOATS
SCALE FOR FIG 4.3 1": 8'
RADIUS 18
25-0"
30 FEET
28-6
SCALE FOR FIG 1.2 2/5": 6'
FIG. 3
SCALE FIG 3. 2/5" = 3


SUPERSTRUCTURE
FOR
BRIDGE BOATS
FIG No 6
FIG No 8
FIG No 1
FIG No 9
Scale for Fig 9
PROPOSED TRUSSED RIB
FOR ROADWAY OF
BOAT BRIDGES
FIG No 10
Scale for Fig 10.11
FIG No 11
Scale for Fig 15
SIDE ELEVATION
END ELEVATION
FIG 12
SECTION A-B
FIG 13
FRONT ELEVATION
OF POOF
PROPOS
HARD
WOOD
SCALE FOR FIG 12, 13, 14


TYPE PLAN
OF
ARRANGEMENTS FOR A
GINNING FAOTORY
SCALE 250 : 1
FACTORIES
RY. STATION
PACA ROAD FROM STATION TO CITY
P. ROAD FROM STATION TO GO DOWN
RY. SERVANTS HOUSES
SERVENTS HOUSE
ENGINEERS H
OFFICE
COALSTONE
Chimney
GINNING
ENGINE HOUSE
PRESS HOUSE
KAPAS PLATFORM
Manager's H.
COTTON GODOWN
SERVANTS H
LATRINE
RY. STORE
RY. FENCING
648
706
100

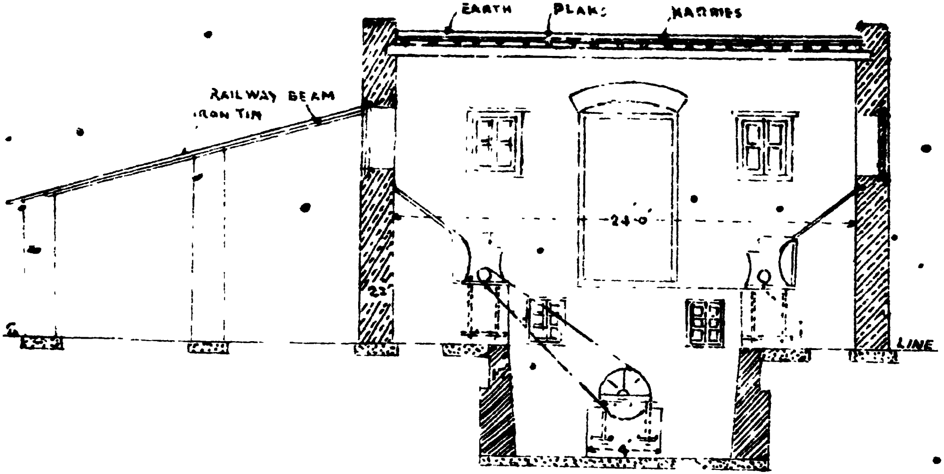


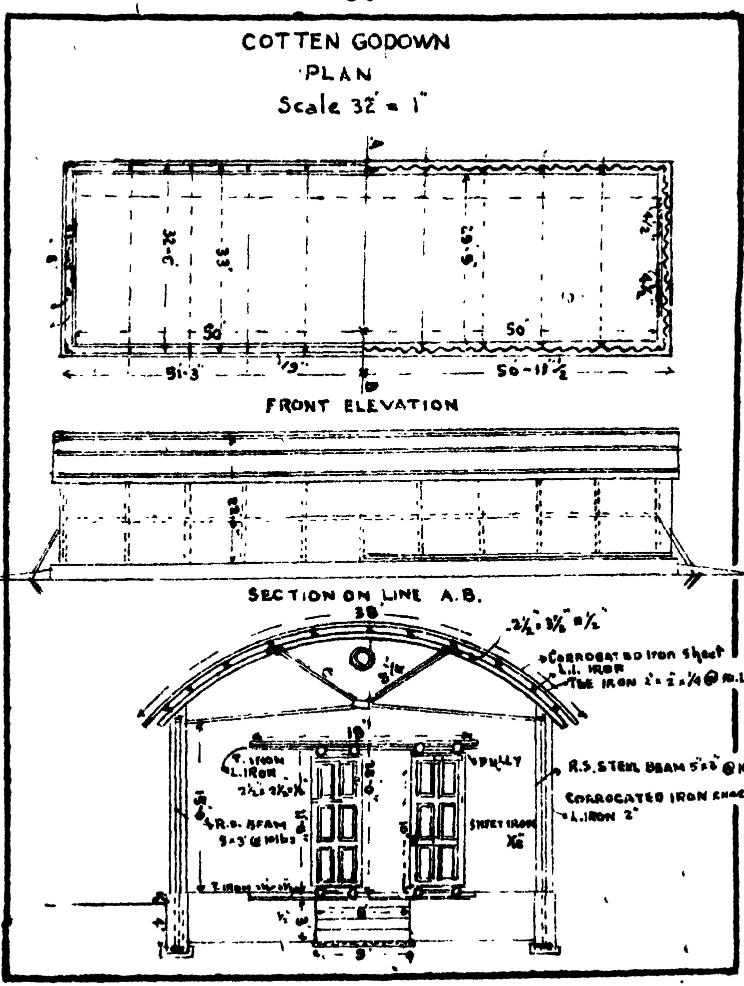
GINNING FACTORY MALER COTLA
HALF PLAN
SCALE 10:1'
A

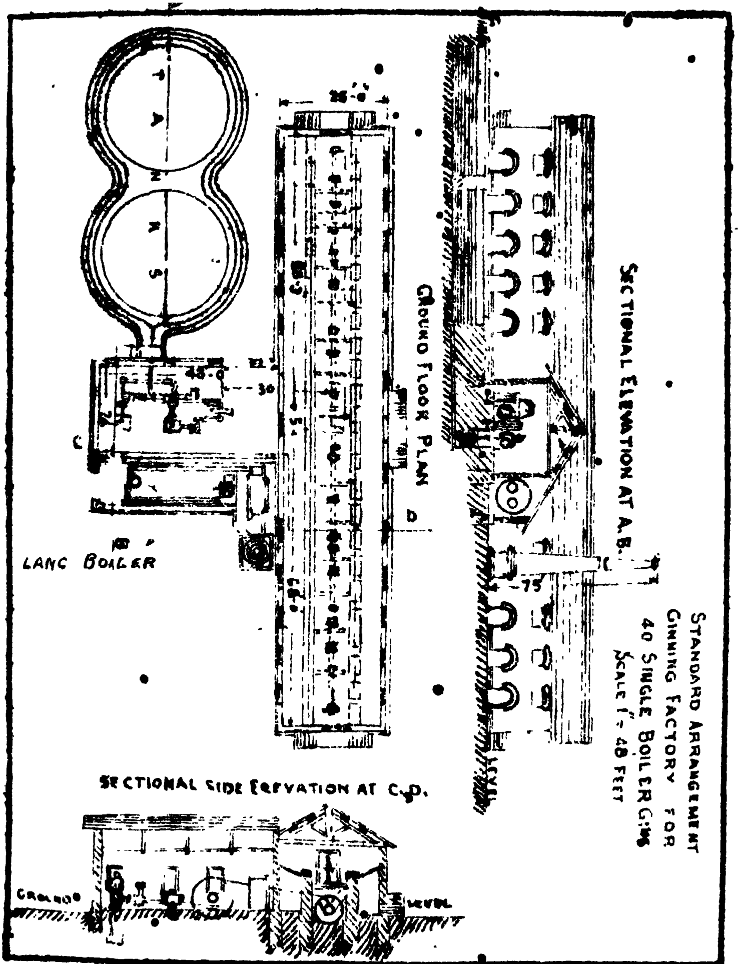
GINNING FACTORY MALER KOTLA

SECTION ON A.B

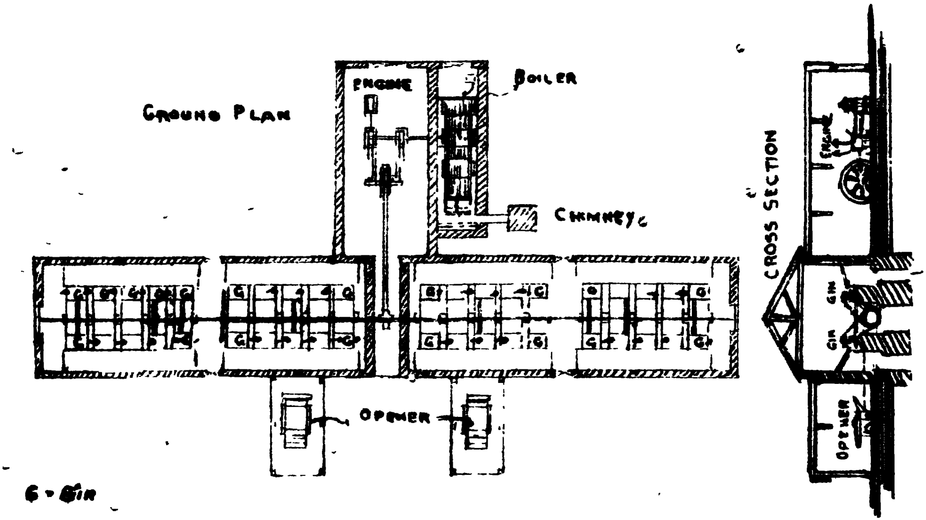
Scale -10'=1

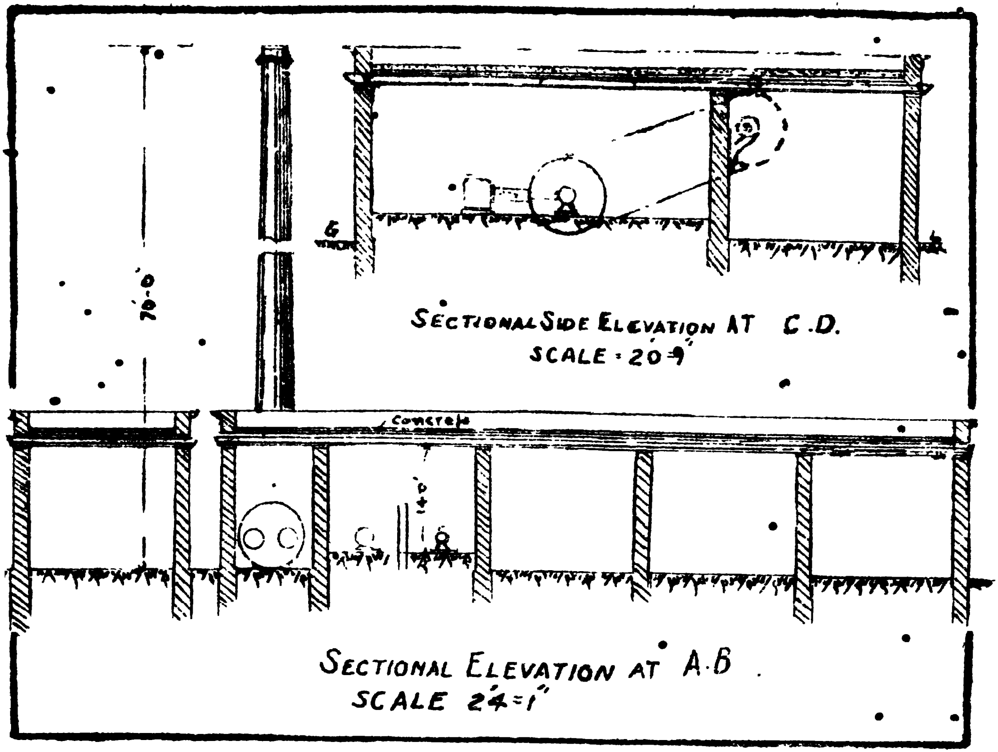


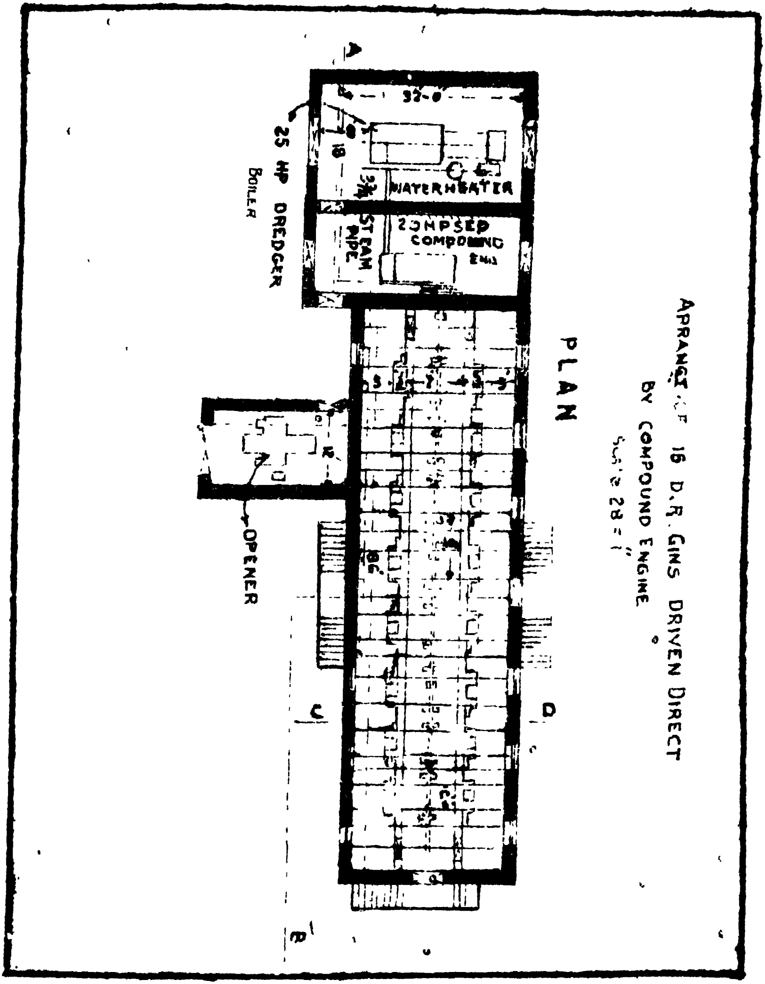

COTTEN GODOWN
PLAN
Scale 32' = 1"
51-3
50-11 1/2
50
FRONT ELEVATION
SECTION ON LINE A.B.
38'
CORROGATED IRON SHEET
L.I. IRON
R.S. STEEL BEAM
CORROGATED IRON SHEET
PULLY
SHEET IRON
9'


STANDARD ARRANGEMENT
GINNING FACTORY FOR
40 SINGLE BOILER GINS
SCALE 1" = 48 FEET
SECTIONAL ELEVATION AT A.B.
GROUND FLOOR PLAN
LANC BOILER
SECTIONAL SIDE ELEVATION AT C.D.
GROUND LEVEL

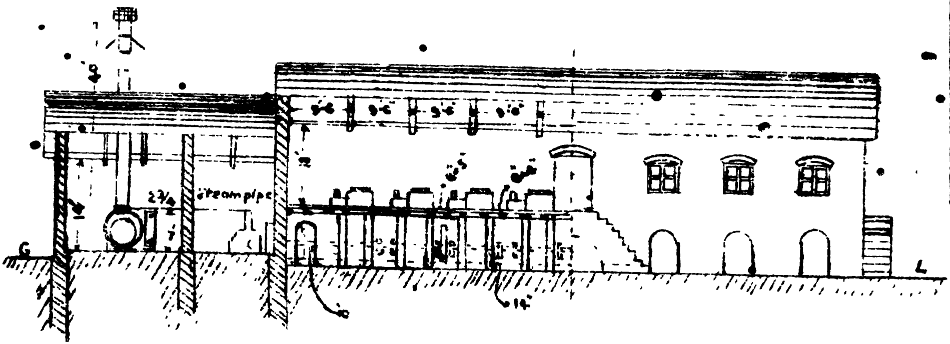
PLAN OF
Cotton Ginning Factory.
to contain 40 Platts Single Roller Gins approximately
Scale 40′ = 1″

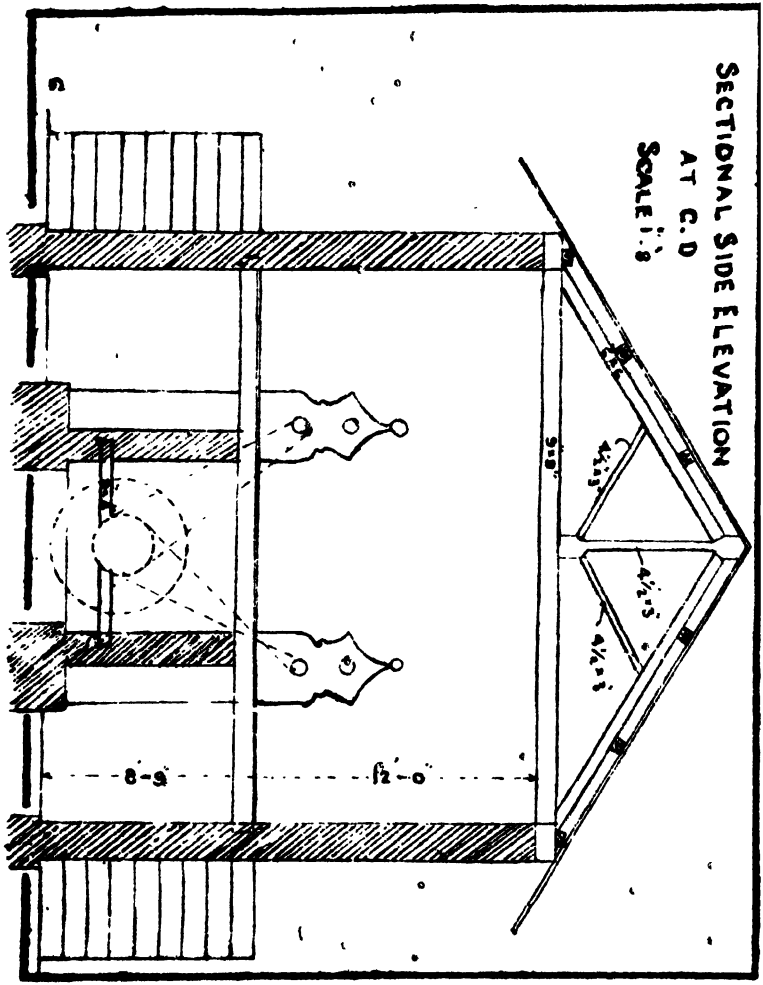



70-0
Sectional Side Elevation at C.D.
Scale = 20-1"
Concrete
14-0
Sectional Elevation at A.B.
Scale 24'=1"


ARRANGT OF 16 D.R. GINS DRIVEN DIRECT
BY COMPOUND ENGINE
PLAN
25 HP DREDGER
BOILER
WATERHEATER
STEAM PIPE
COMPOUND
ENG
OPENER
32-0
A
B
C
D

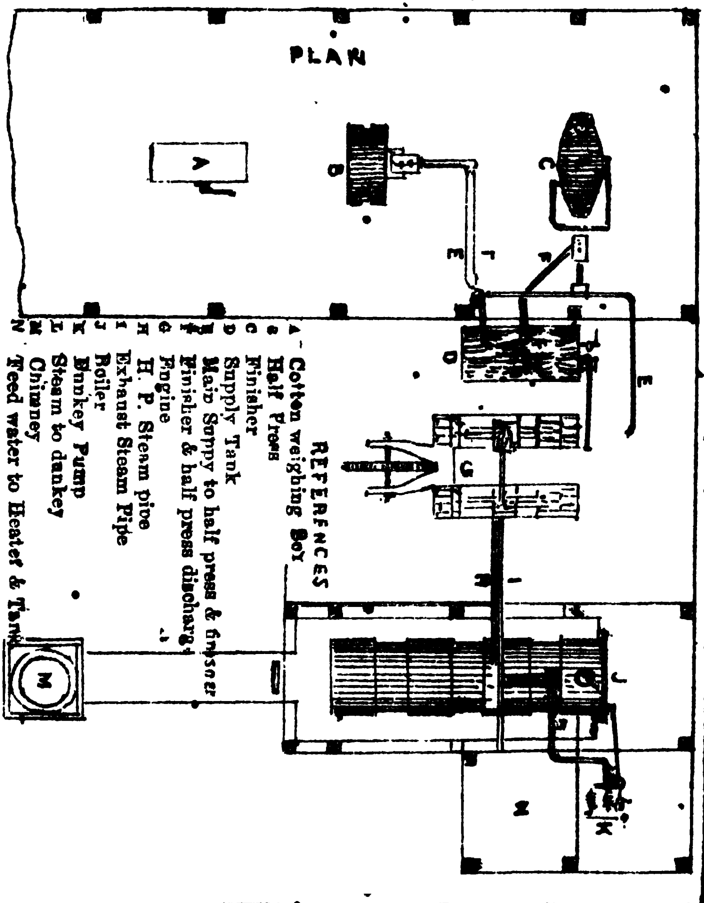
SECTIONAL ELEVATION AT A.B
SCALE 28.1"

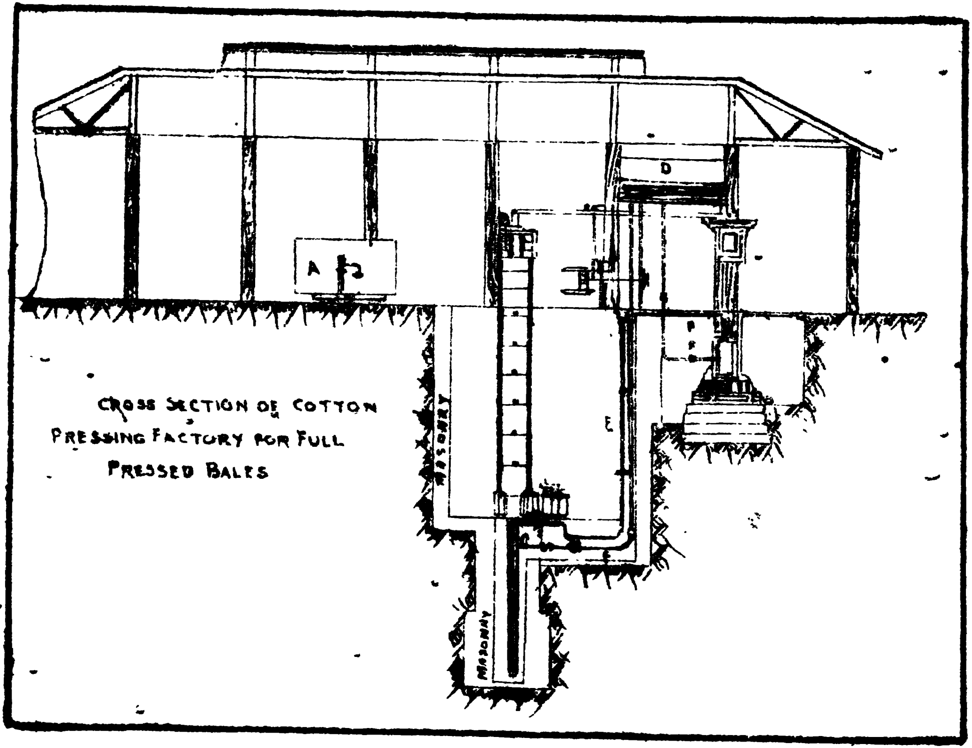




SECTIONAL SIDE ELEVATION AT C.D SCALE 1:8

COTTON PRESSING FACTORY

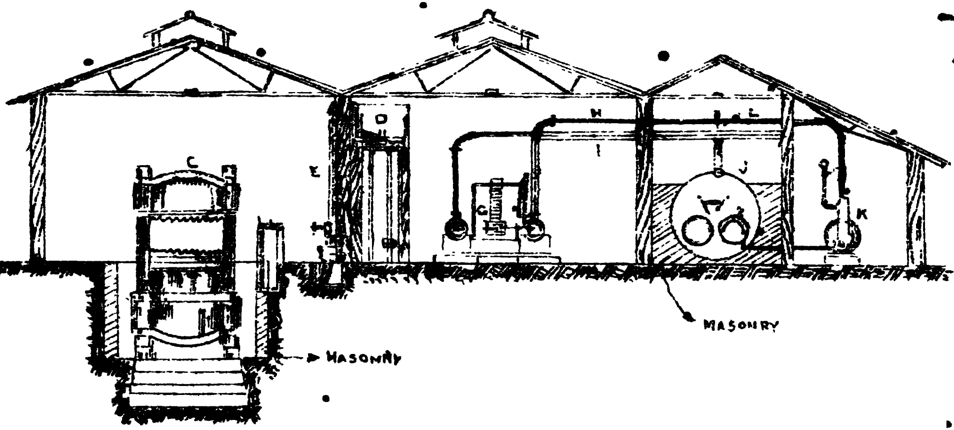


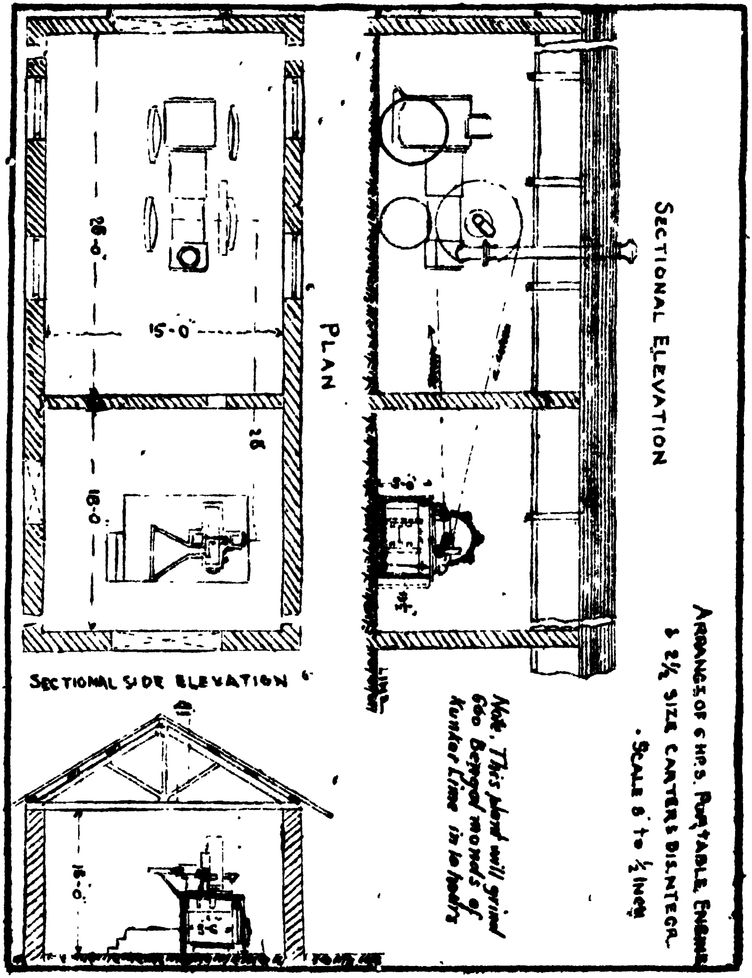


CROSS SECTION OF COTTON PRESSING FACTORY FOR FULL PRESSED BALES

COTTON PRESSING FACTORY

HYDRAULIC BALING PLANT FOR FULL PRESSED COTTON BALE ETC:



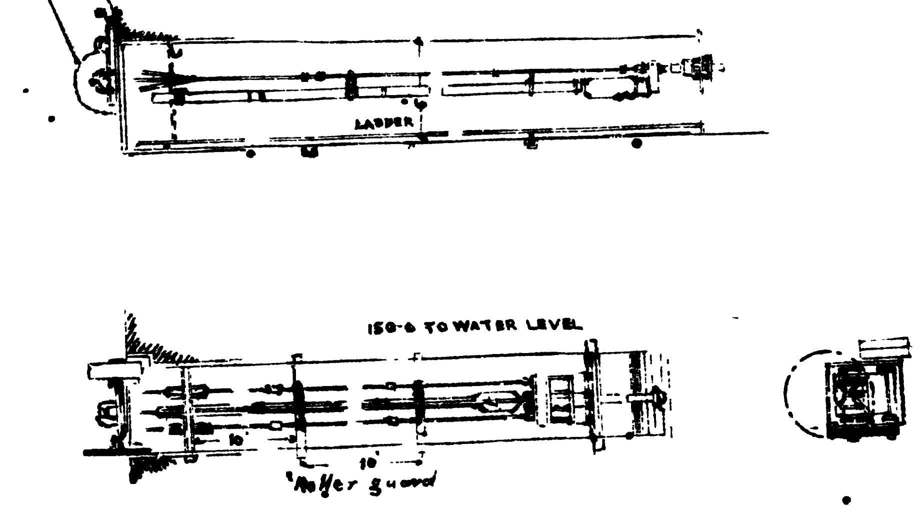


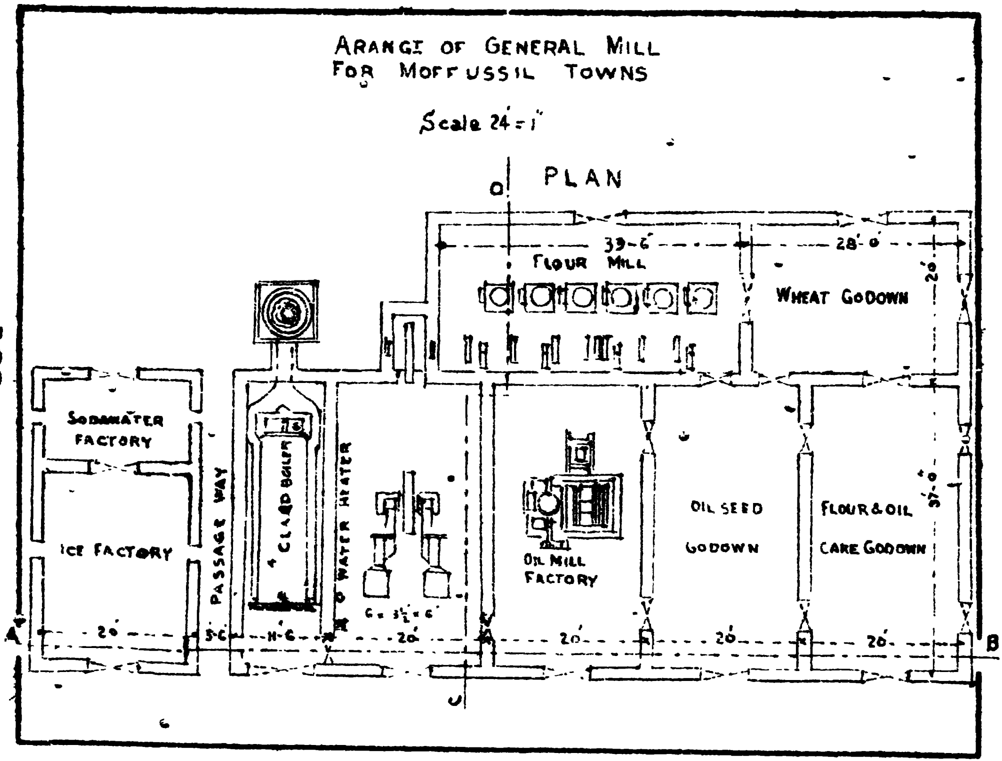
PLAN
26-0"
15-0"
18-0"
SECTIONAL ELEVATION
SECTIONAL SIDE ELEVATION
15-0"
ARRANG. OF 6 H.P.S. PORTABLE ENGINE & 2½ SIZE CARTERS DISINTEGR.
SCALE 8' to ½ INCH
Note. This plant will grind 600 Bengal maunds of kunkar Lime in 10 hours

ARRANGEMENT OF 7″ x 18″ TREBLE DEEP

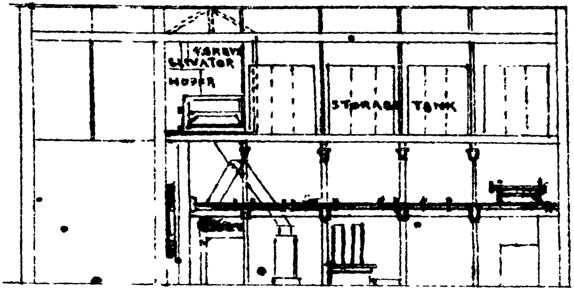
WELL PUMP

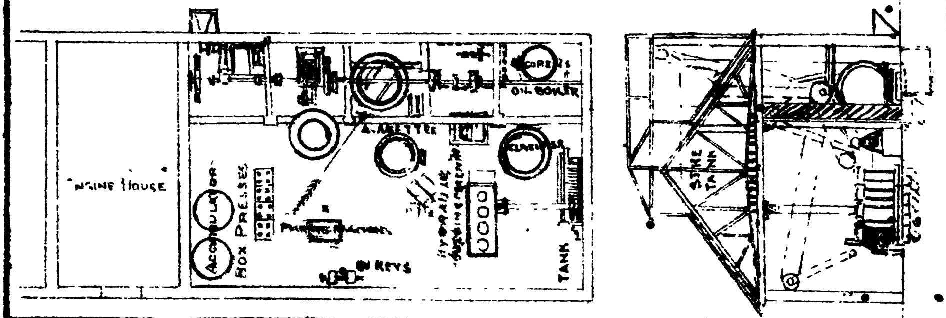
Scale ½″ = 1 Feet

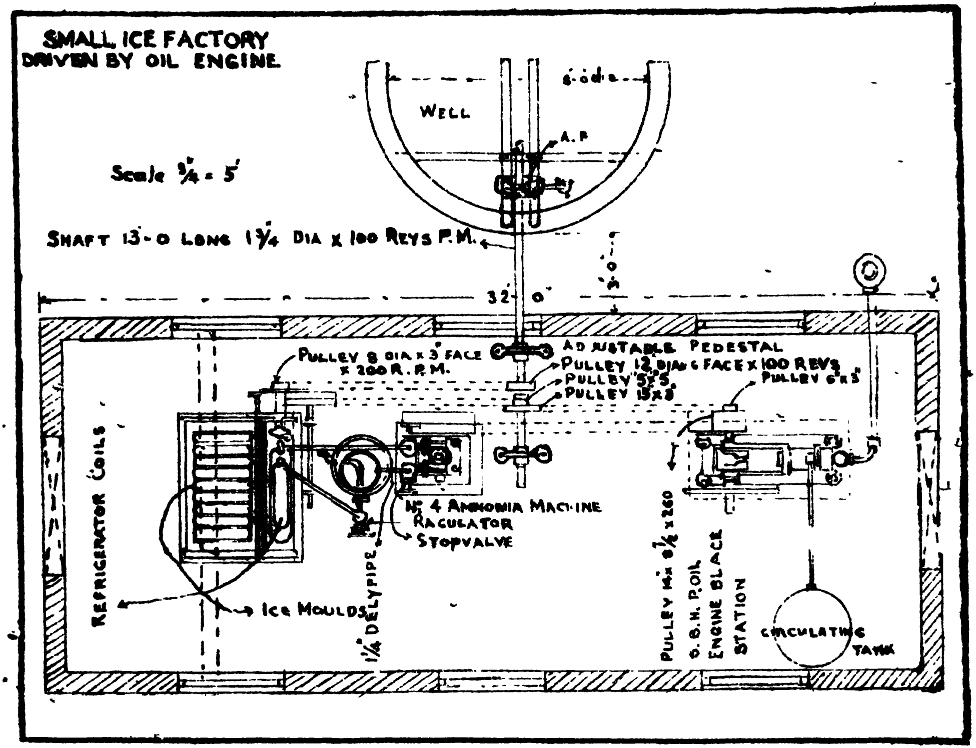


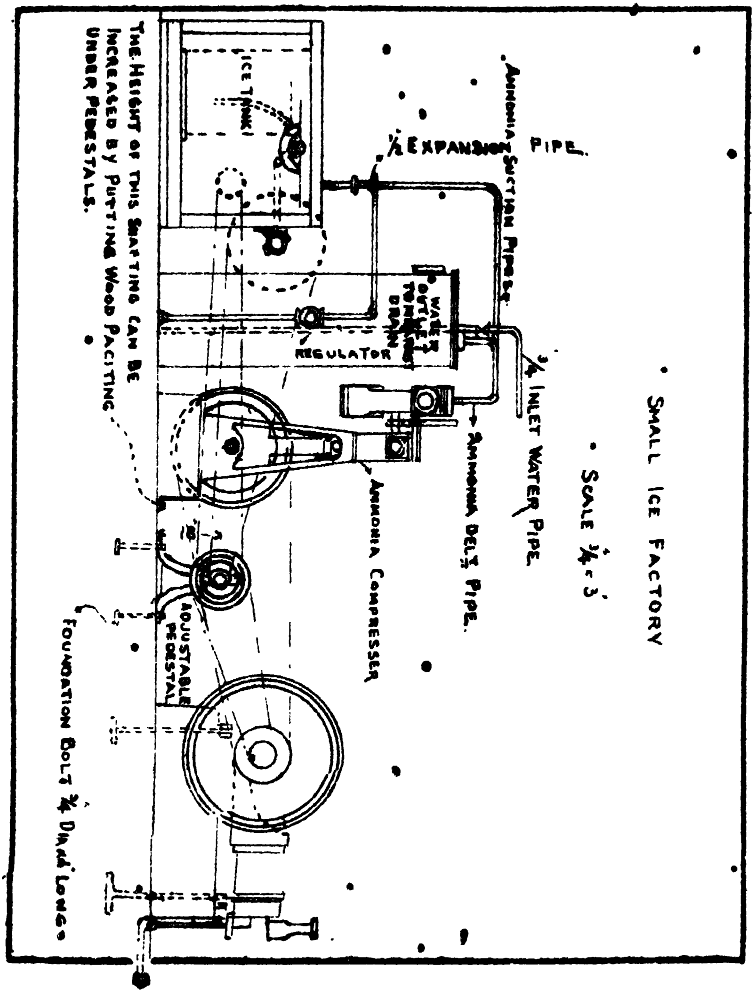

ARANGt OF GENERAL MILL
FOR MOFFUSSIL TOWNS
Scale 24'=1"
PLAN
FLOUR MILL
WHEAT GODOWN
SODAWATER FACTORY
ICE FACTORY
PASSAGE WAY
CLARD BOILER
WATER HEATER
OIL MILL FACTORY
OIL SEED GODOWN
FLOUR & OIL CAKE GODOWN
39-6
28-0
37-0
20
3-6
11-6
A
B
C
D

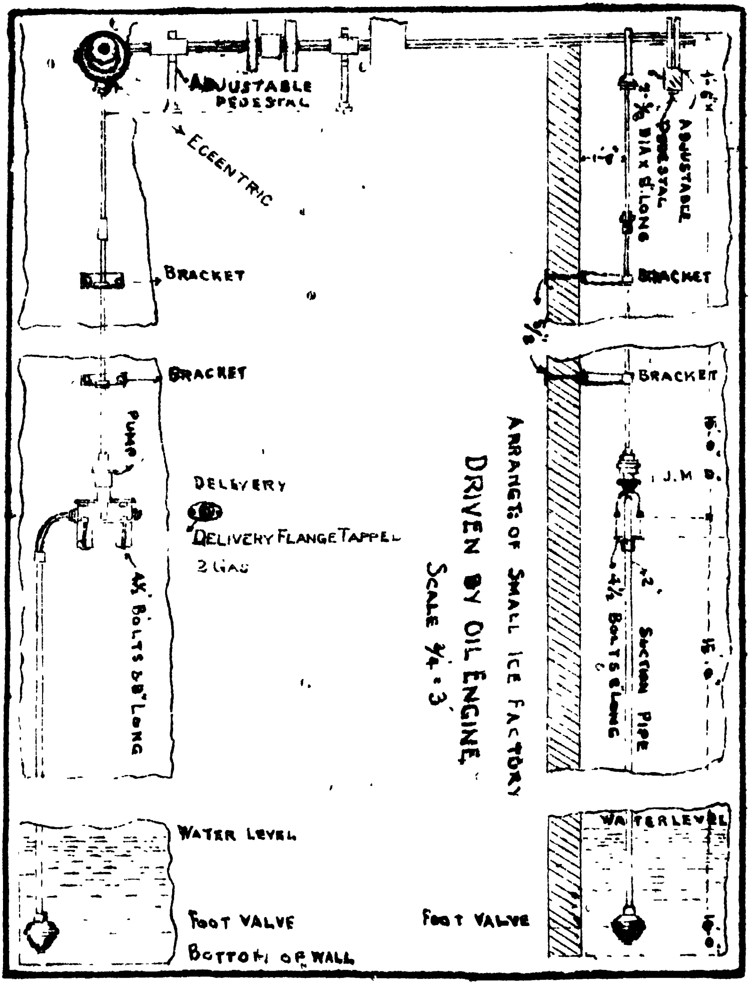
ARRANGEMENT OF OIL MILL PLANT
SUITABLE FOR CRUSHING 10 (TEN) TONS
OF OIL SEEDS PER DAY OF TEN HOURS
Scale 1/4 inch = 7 Feet

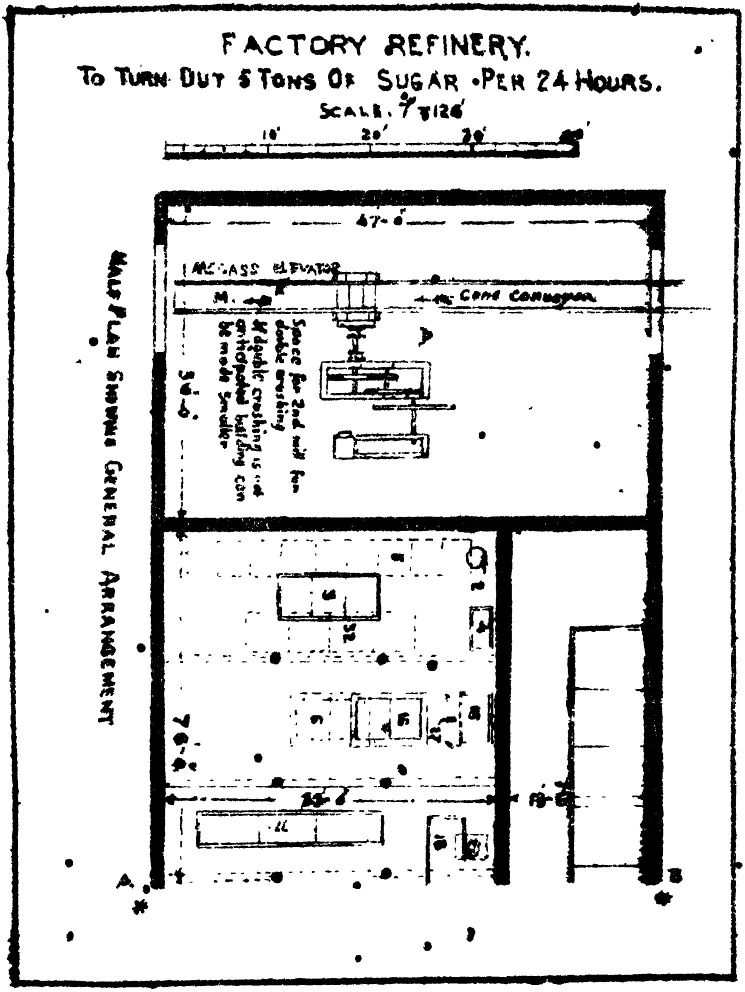




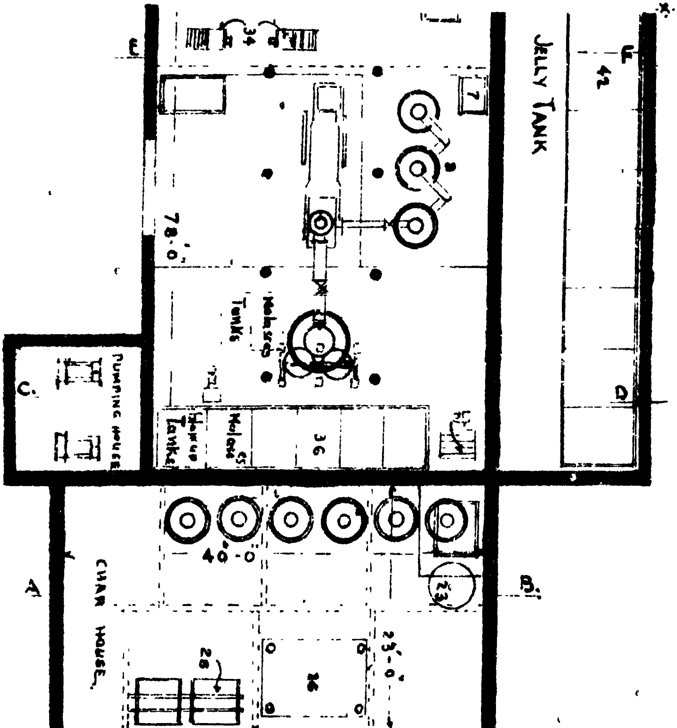

SMALL ICE FACTORY
DRIVEN BY OIL ENGINE
Scale 3/4" = 5'
WELL
A.P
SHAFT 13-0 LONG 1 3/4 DIA x 100 REVS P.M.
32-0"
ADJUSTABLE PEDESTAL
PULLEY 8 DIA x 3 FACE x 200 R.P.M.
PULLEY 12 DIA 6 FACE x 100 REVS
PULLEY 5 x 5
PULLEY 15 x 8
PULLEY 6 x 3
No 4 AMMONIA MACHINE
RAGULATOR
STOPVALVE
REFRIGERATOR COILS
ICE MOULDS
1 1/4 DELYPIPE
PULLEY 14 x 8 1/2 x 260
6. B.H. P. OIL
ENGINE BLACE
STATION
CIRCULATING
TANK

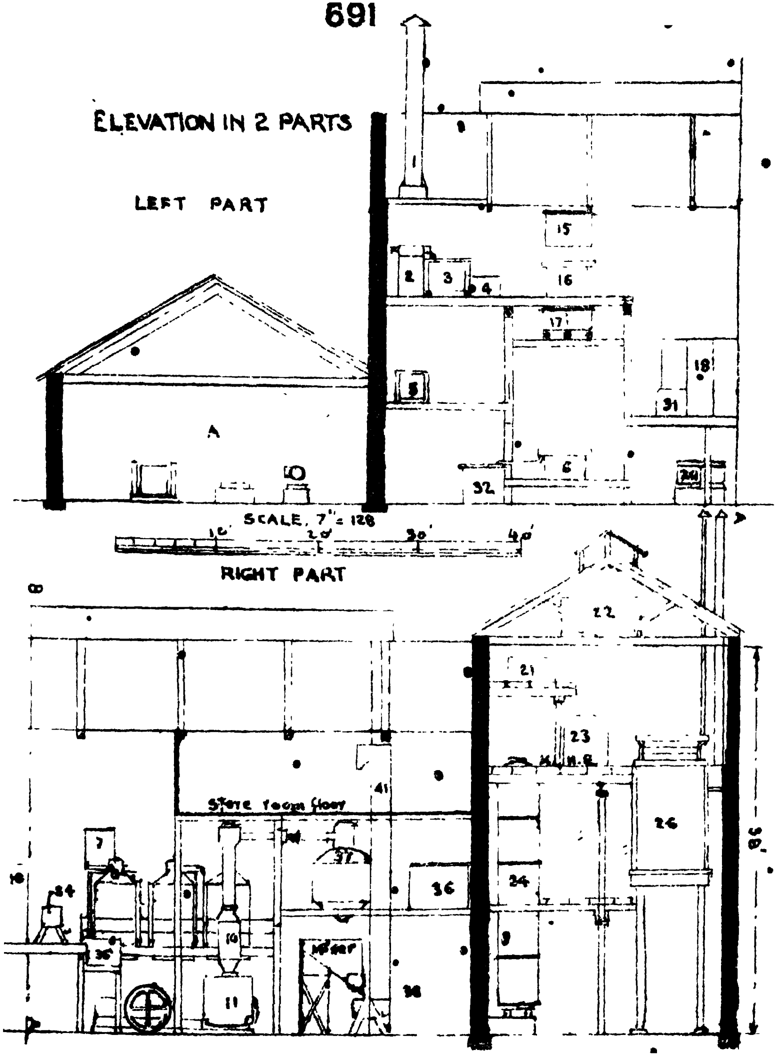

SMALL ICE FACTORY
AMMONIA SUCTION PIPES
½ EXPANSION PIPE.
¾ INLET WATER PIPE.
AMMONIA DEL'Y PIPE.
AMMONIA COMPRESSER
REGULATOR
ICE TANK
ADJUSTABLE PEDESTAL
FOUNDATION BOLT
THE HEIGHT OF THIS SHAFTING CAN BE INCREASED BY PUTTING WOOD PACKING UNDER PEDESTALS.


ADJUSTABLE PEDESTAL
ECCENTRIC
BRACKET
BRACKET
PUMP
DELIVERY
DELIVERY FLANGE TAPPED
2 GAS
4½ BOLTS 5½" LONG
WATER LEVEL
FOOT VALVE
BOTTOM OF WALL
ARRANGT OF SMALL ICE FACTORY
DRIVEN BY OIL ENGINE
SCALE ¾ = 3'
ADJUSTABLE PEDESTAL
BRACKET
BRACKET
J.M.D.
SUCTION PIPE
WATER LEVEL
FOOT VALVE

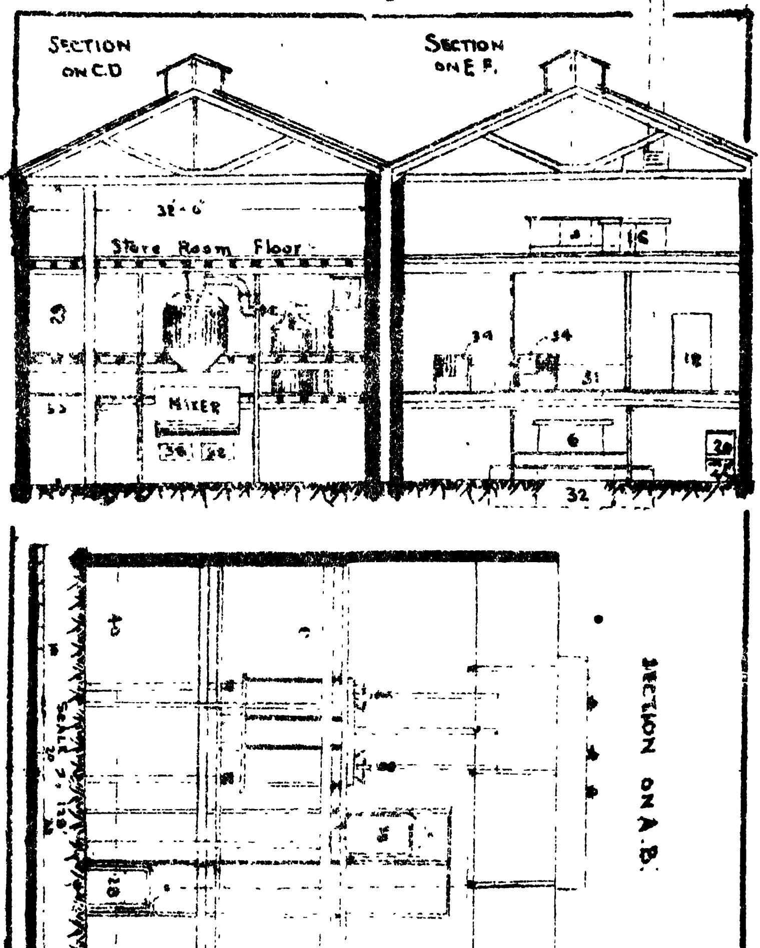

FACTORY REFINERY.
To Turn Out 5 Tons Of Sugar Per 24 Hours.
47-6
Megass Elevator
Cane Conveyor
Space for 2nd mill for double crushing
Half Plan Showing General Arrangement
A
B

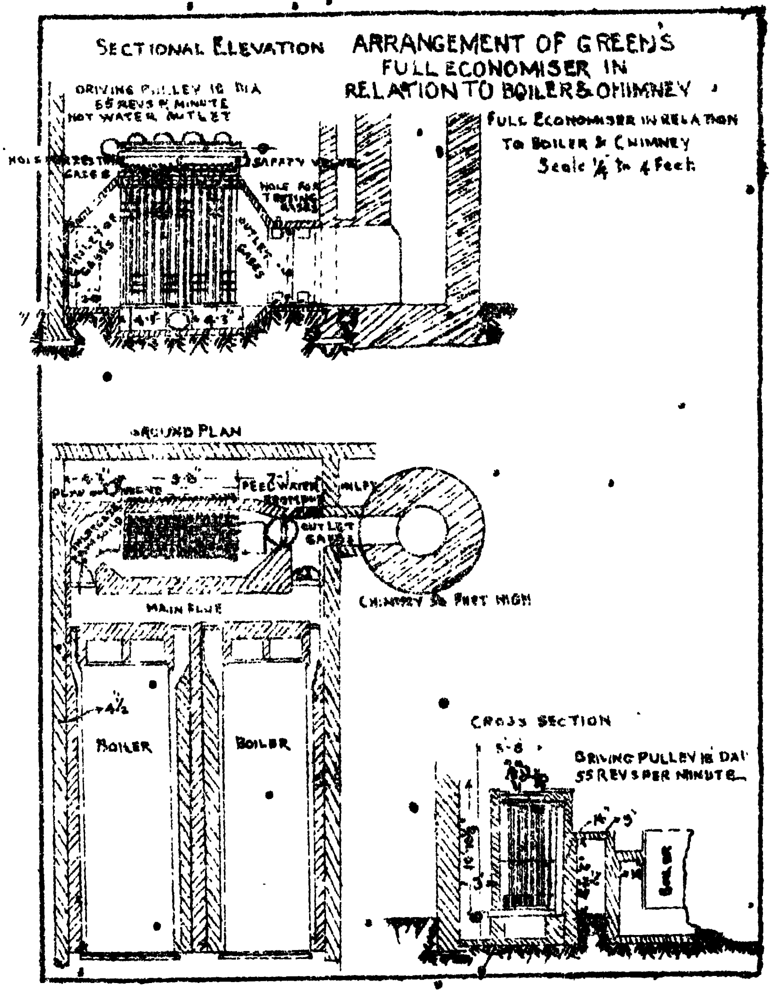
OTHER HALF PLAN OF THE FACTORY.



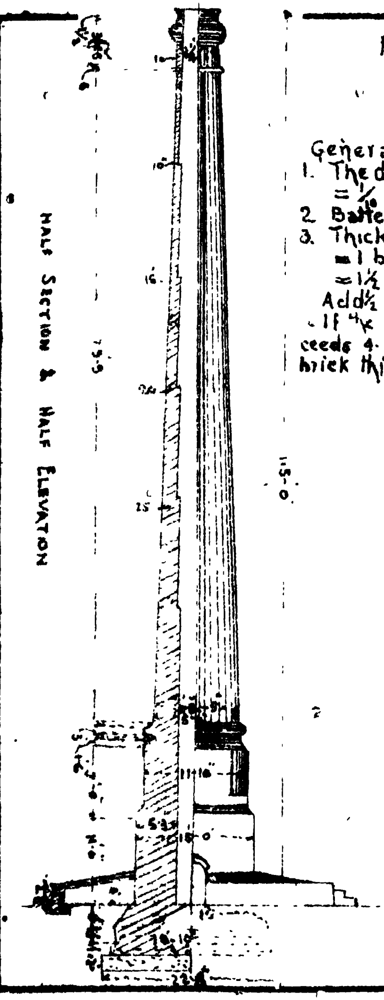

ELEVATION IN 2 PARTS
LEFT PART
A
1
2
3
4
5
6
15
16
17
18
31
32
SCALE, 7" = 128
10'
20'
30'
40'
RIGHT PART
State room floor
7
10
11
21
22
23
24
26
36
37
38
41

E82


SECTION ON C.D
SECTION ON E.F.
32'-0"
Store Room Floor
MIXER
SECTION ON A.B.


SECTIONAL ELEVATION
ARRANGEMENT OF GREEN'S FULL ECONOMISER IN RELATION TO BOILER & CHIMNEY
FULL ECONOMISER IN RELATION TO BOILER & CHIMNEY
Scale ¼ In 4 Feet
DRIVING PULLEY 18 DIA
55 REVS P. MINUTE
HOT WATER OUTLET
SAFETY VALVE
HOLE FOR TESTING GASES
INLET OF GASES
OUTLET GASES
GROUND PLAN
FEED WATER
INLET
OUTLET GASES
MAIN FLUE
CHIMNEY 50 FEET HIGH
BOILER
BOILER
CROSS SECTION
DRIVING PULLEY 18 DIA
55 REVS PER MINUTE

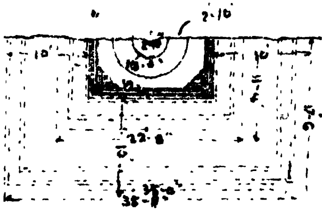
FACTORY CHIMNEYS

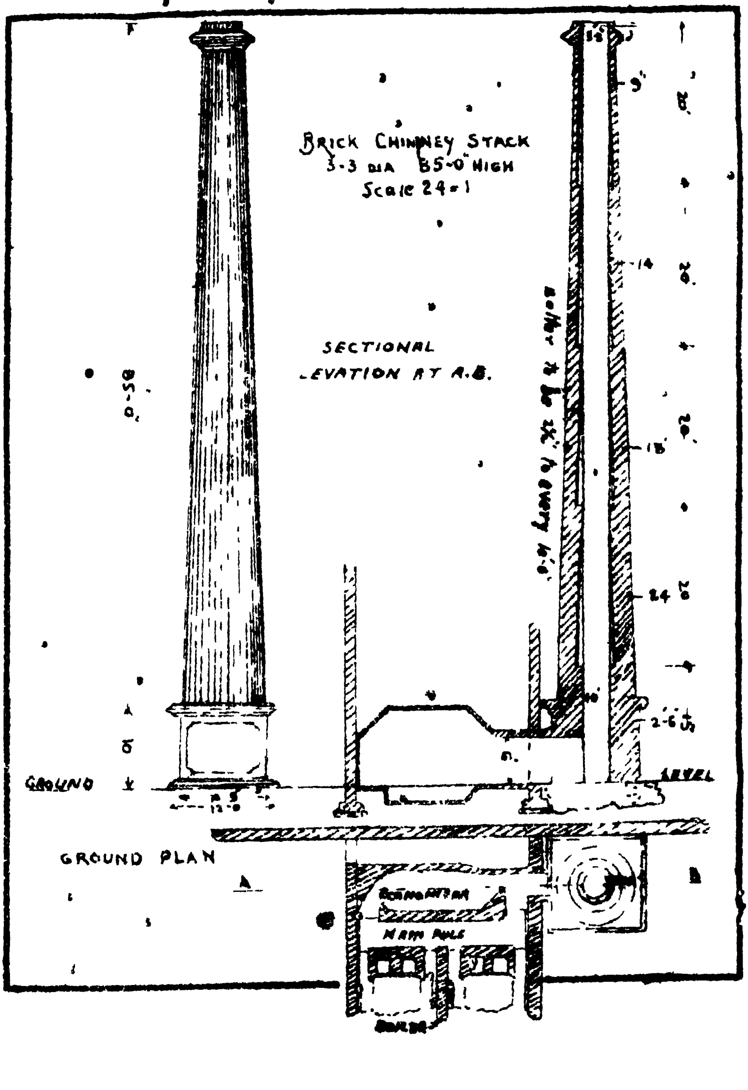


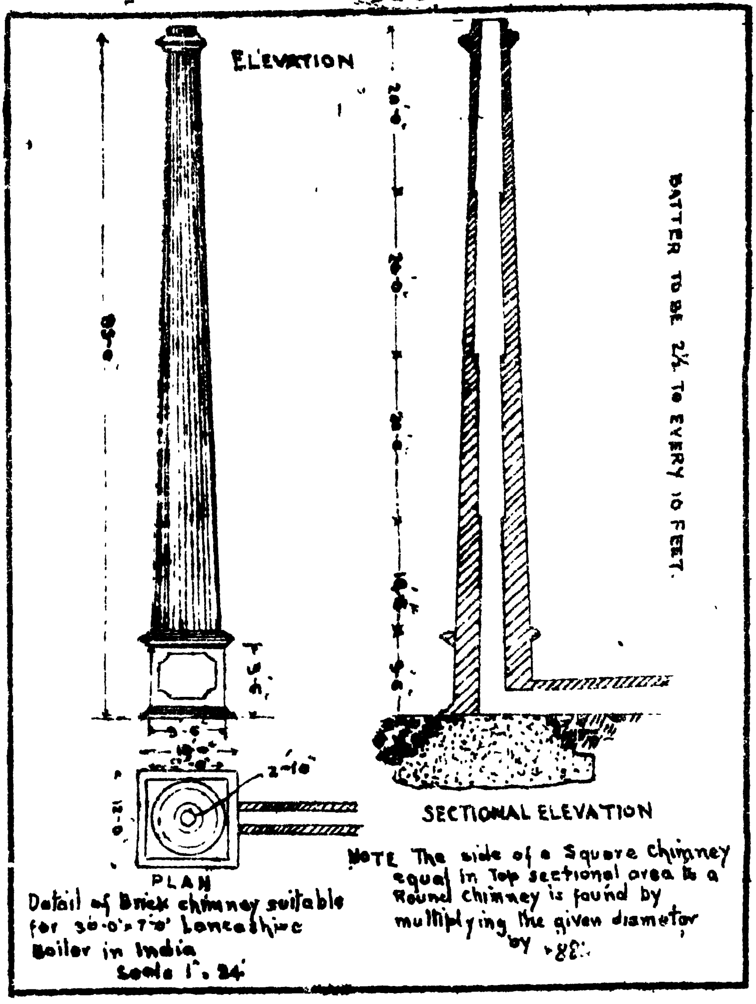
General Rules for Brick Chimneys

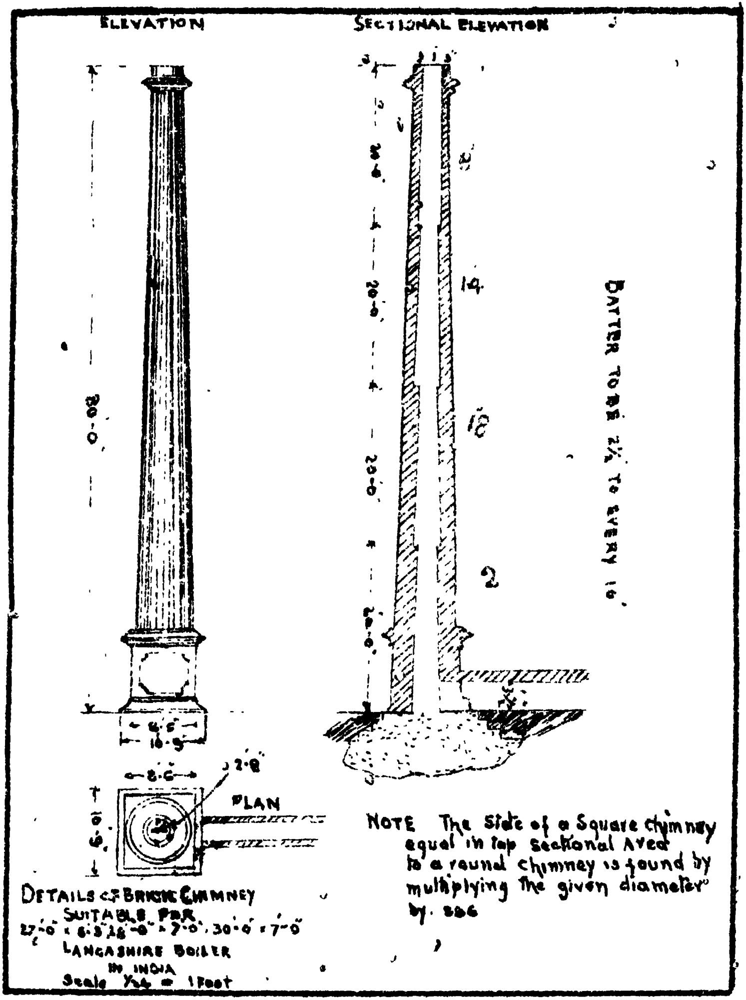
1. The diameter of the base $= \frac{1}{10}$ to $\frac{1}{12}$ of height
2. Batter of chimneys $= \frac{1}{40}$
3. Thickness of brick work
   = 1 brick from top to 25 ft below top.
   = 1½ " " 25 to 50 ft below top.
   Add ½ " for every 25 ft from the top.
   If the inside diameter at the top exceeds 4. 6 the top length should be 1½ brick thick

PLAN




BRICK CHIMNEY STACK
3-3 DIA 85-0" HIGH
Scale 24=1
SECTIONAL
ELEVATION AT A.B.
GROUND
LEVEL
GROUND PLAN

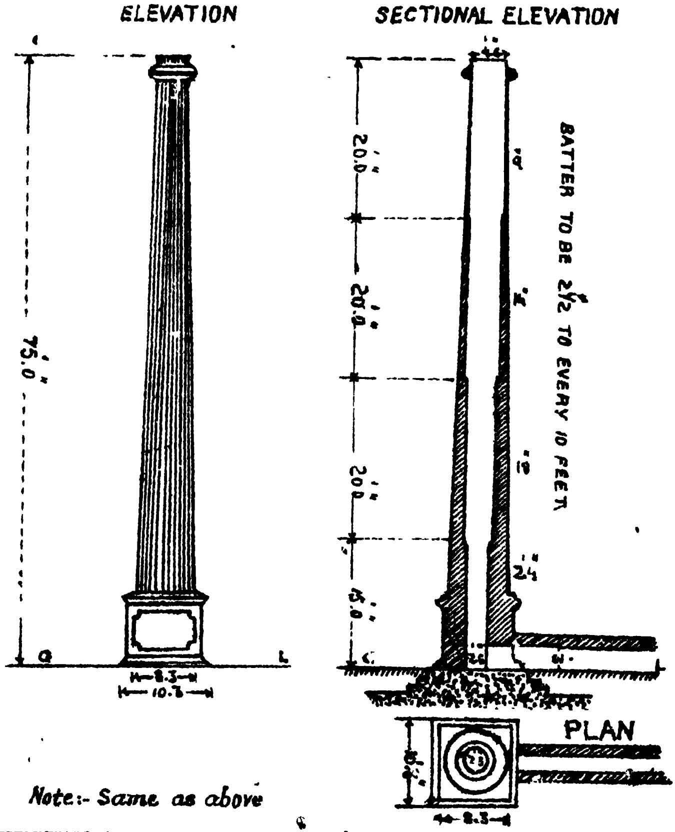

ELEVATION
SECTIONAL ELEVATION
BATTER TO BE 2½ TO EVERY 10 FEET.
PLAN
2'-10"
NOTE The side of a Square Chimney equal in Top sectional area to a Round chimney is found by multiplying the given diameter by ·88.
Detail of Brick chimney suitable for 30'-0"×7'-0" Lancashire Boiler in India
Scale 1" = 24'

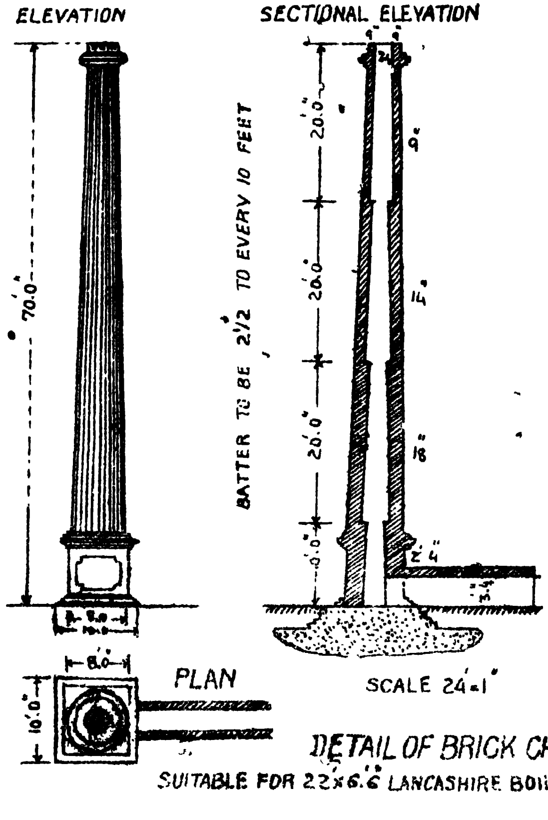

ELEVATION
SECTIONAL ELEVATION
BATTER TO BE 2½ TO EVERY 10
PLAN
NOTE The side of a Square chimney equal in top sectional Area to a round chimney is found by multiplying the given diameter by .886
DETAILS OF BRICK CHIMNEY
SUITABLE FOR
27'-0" × 6'-3", 28'-0" × 7'-0", 30'-0" × 7'-0"
LANCASHIRE BOILER
IN INDIA
Scale 1/24 = 1 Foot

DETAIL OF BRICK CHIMNEY.

SUITABLE FOR 24'.0"x6'.6" LANCASHIRE BOILER USED IN INDIA.

SCALE. 24' 1"

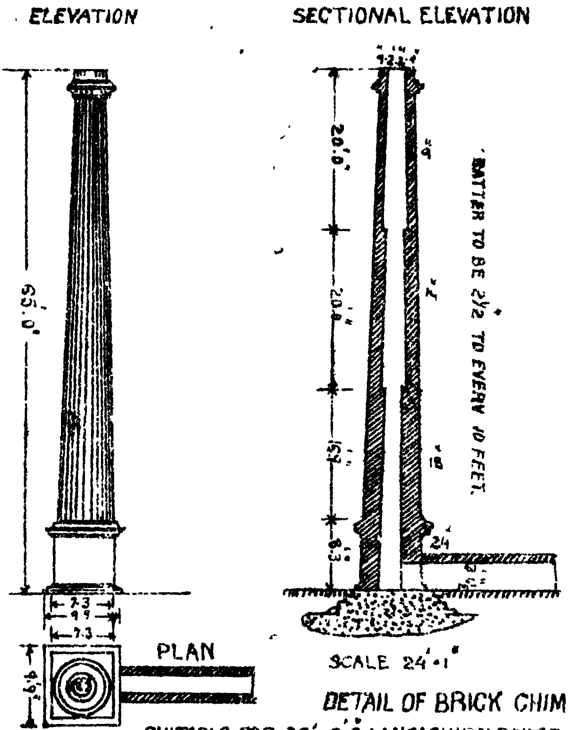




DETAIL OF BRICK CHIMNEY

SUITABLE FOR 22'×6'6" LANCASHIRE BOILER IN INDIA.

NOTE:- THE SIDE OF A SQUARE CHIMNEY EQUAL IN TOP SECTIONAL AREA TO A ROUND CHIMNEY IS FOUND BY MULTIPLYING THE GIVEN DIAMETER BY ·886.



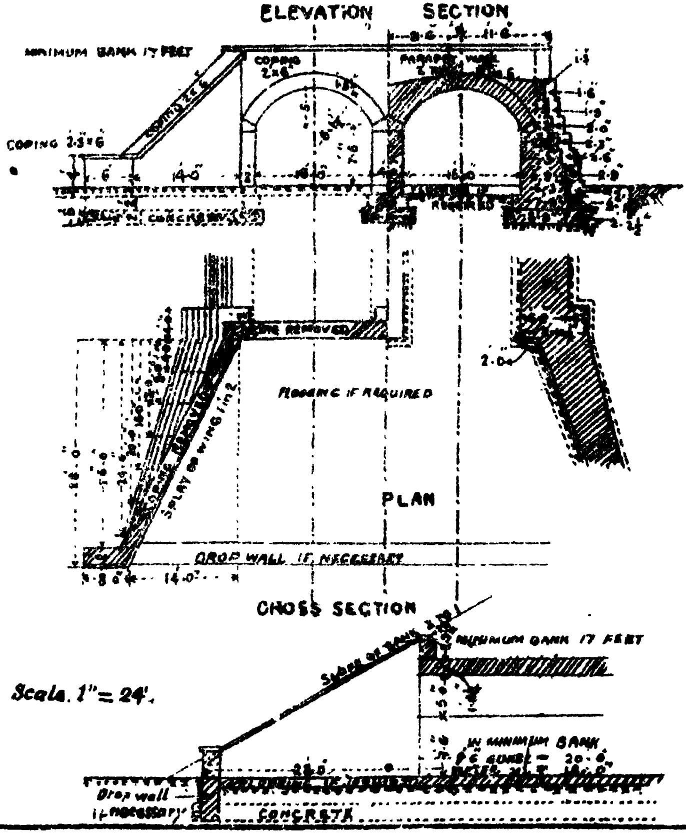
DETAIL OF BRICK CHIMNEY
SUITABLE FOR 20'x6'6" LANCASHIRE BOILER IN INDIA.

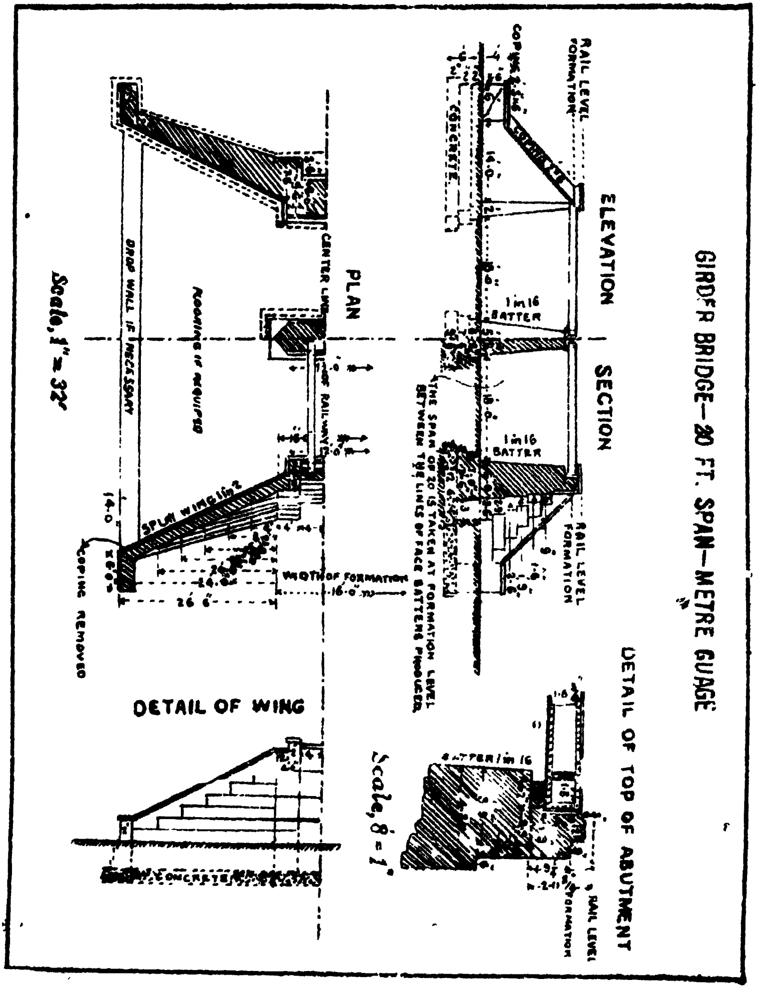
NOTE:—
THE SIDE OF A SQUARE CHIMNEY EQUAL IN TOP SECTIONAL AREA TO A ROUND CHIMNEY IS FOUND BY MULTIPLYING THE GIVEN DIAMETER BY .886.

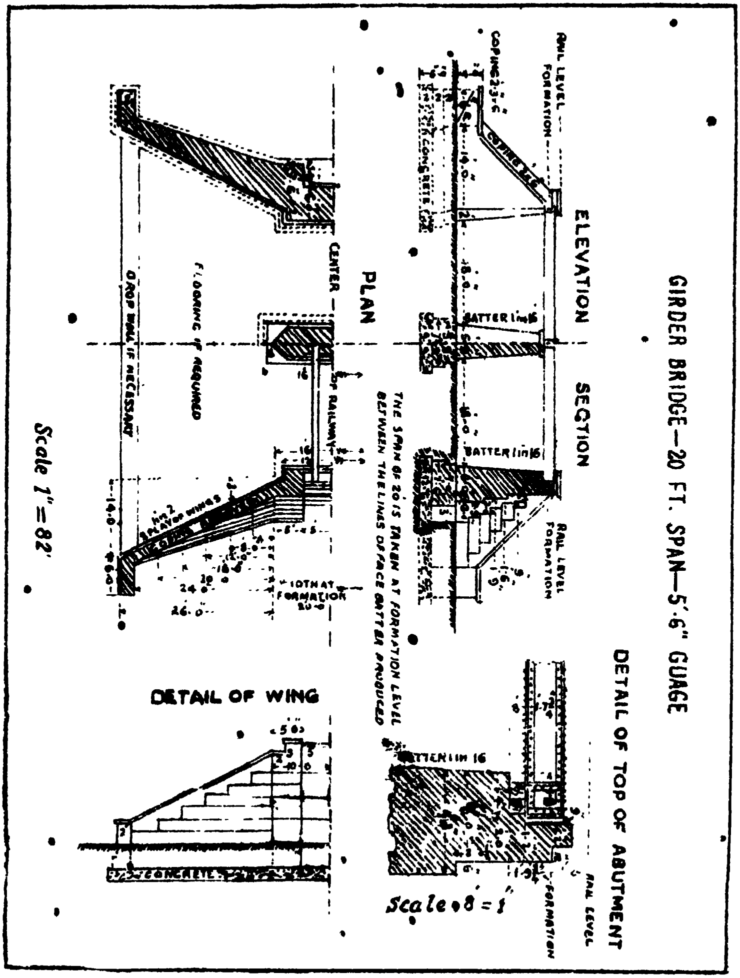
RAILWAY WORKS

(Stone's culverts and Bridges)

ARCHED CULVERT—HEAVY TYPE—15 FT. SPAN

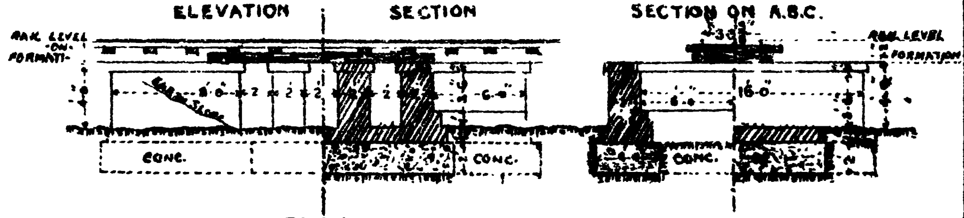


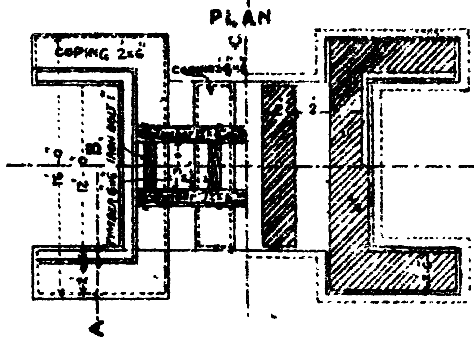

GIRDER BRIDGE—20 FT. SPAN—METRE GUAGE
ELEVATION
SECTION
PLAN
DETAIL OF TOP OF ABUTMENT
DETAIL OF WING
RAIL LEVEL
FORMATION
1 in 16 BATTER
CONCRETE
CENTER LINE
WIDTH OF FORMATION
16-0"
THE SPAN OF 20 IS TAKEN AT FORMATION LEVEL BETWEEN THE LINES OF FACE BATTERS PRODUCED
DROP WALL IF NECESSARY
SPLAY WINGS
COPING REMOVED
Scale, 1" = 32'
Scale, 8' = 1"


GIRDER BRIDGE—20 FT. SPAN—5'.6" GUAGE
ELEVATION
SECTION
PLAN
DETAIL OF TOP OF ABUTMENT
DETAIL OF WING
RAIL LEVEL
FORMATION
BATTER 1 in 16
CENTER OF RAILWAY
THE SPAN OF 20 IS TAKEN AT FORMATION LEVEL BETWEEN THE LINES OF FACE BATTER PRODUCED
DROP WALL IF NECESSARY
CONCRETE
Scale 1" = 82'
Scale 8 = 1

TYPES OF OPEN & FLAT TOP CULVERTS

OPEN TOP CULVERT—2 FT. SPAN—METRE GUAGE





NOTE —The sleepers shown in the drawings are of the standard dimensions, viz., 8" × 4½" × 6'

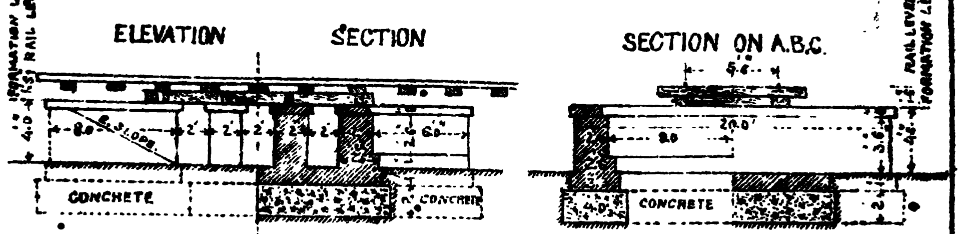
The dimension of 1' 2" between formation and rail level is made up thus —

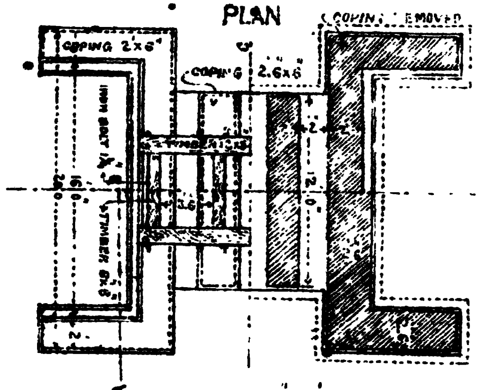
Depth of rail	...	3½	inches.
Sleepers ...	...	4½	,,
Longitudinal timbers		6	,,
Total	...	14	inches.

The bolts to be 1" diameter and 5' 2" long under head to point, each bolt being provided with a nut and two square washers, 4½" square × ¼" thick

Scale, 1" = 12'

OPEN TOP CULVERT—2 FT. SPAN—5′-6″ GUAGE





SCALE 1″=12″

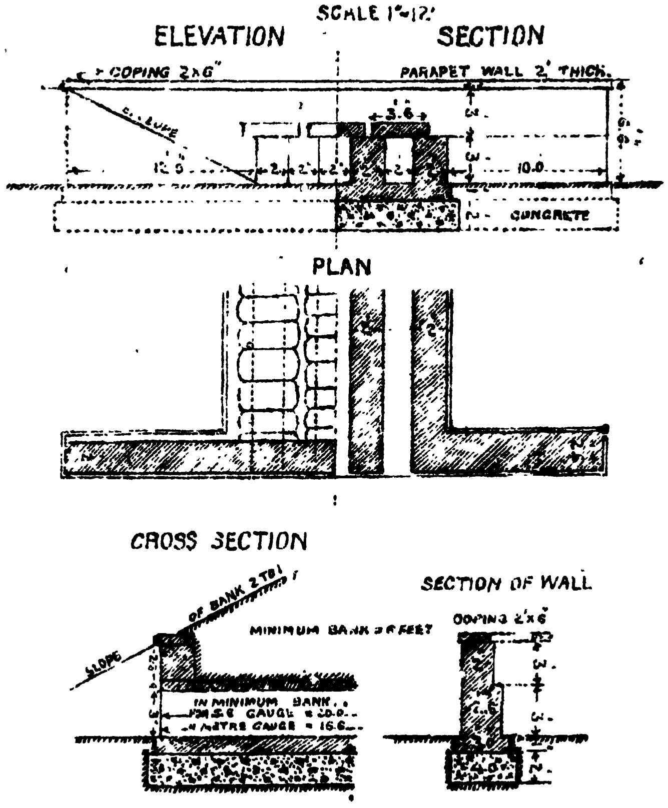
NOTE.—The sleepers shown in the drawing are of the standard dimensions, viz., 10″ x 5″ x 9′ 6.″

The dimension of 1′ 6″ between formation and rail level is made up thus:—

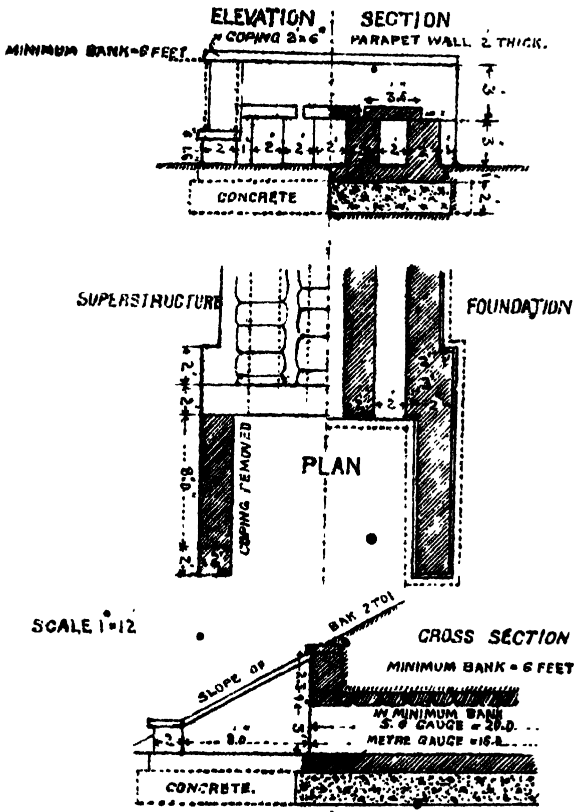
Depth of rail	...	... 5	inches.
Sleepers ...	...	... 5	"
Longitudinal timbers		... 8	"
Total		... 18	inches.

The bolts to be 1¼″ diameter and 7′ 3″ under head to point, each bolt being provided with a nut and two square washers, 6″ square X ½″ thick.

FLAT TOP CULVERT-2 FT. SPAN—BOTH GUAGES WITH RETURN WALLS

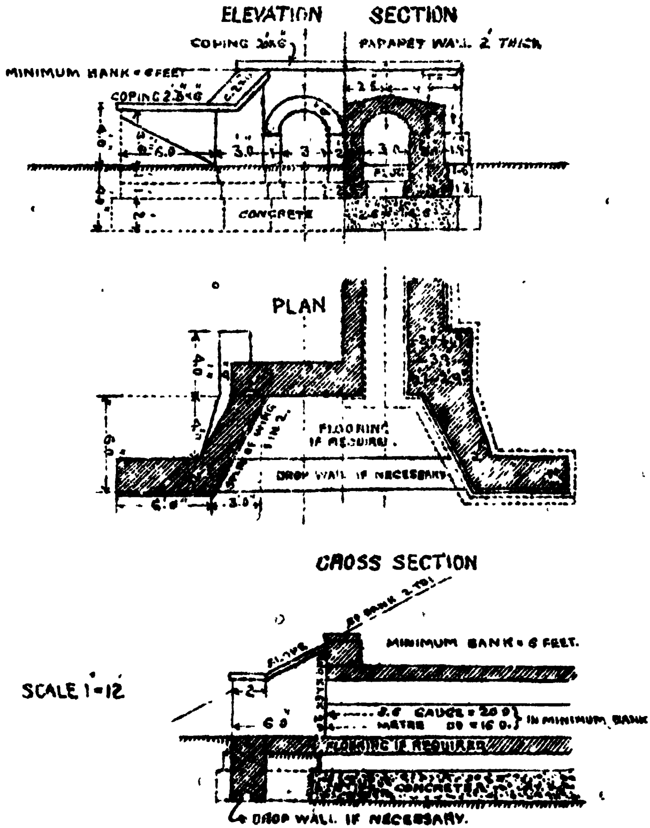


FLAT TOP CULVERT–2 FT. SPAN–BOTH GUAGES WITH SQUARE WING WALLS



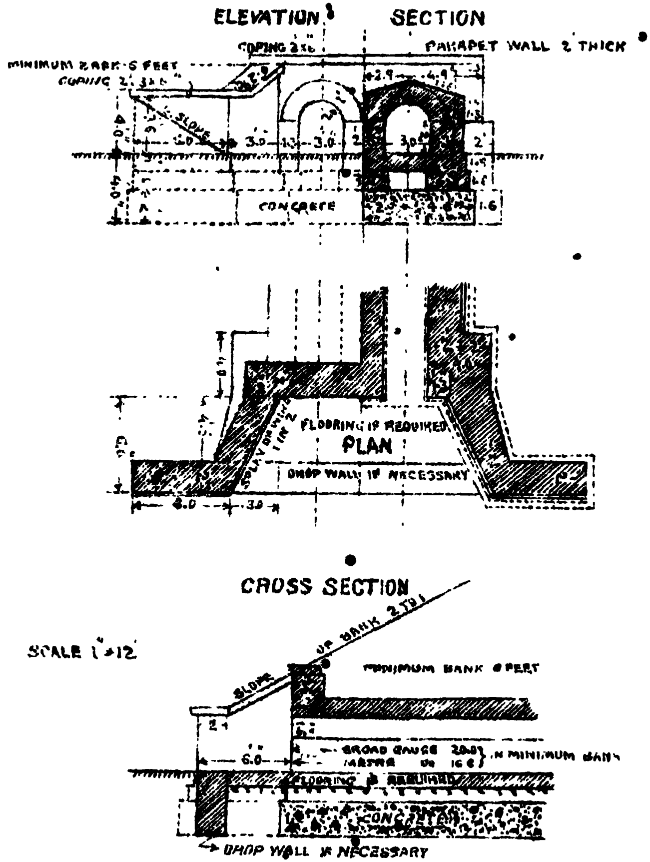
TYPES OF ARCHED CULVERTS—BOTH GUAGES

3 Feet Span—Light Type



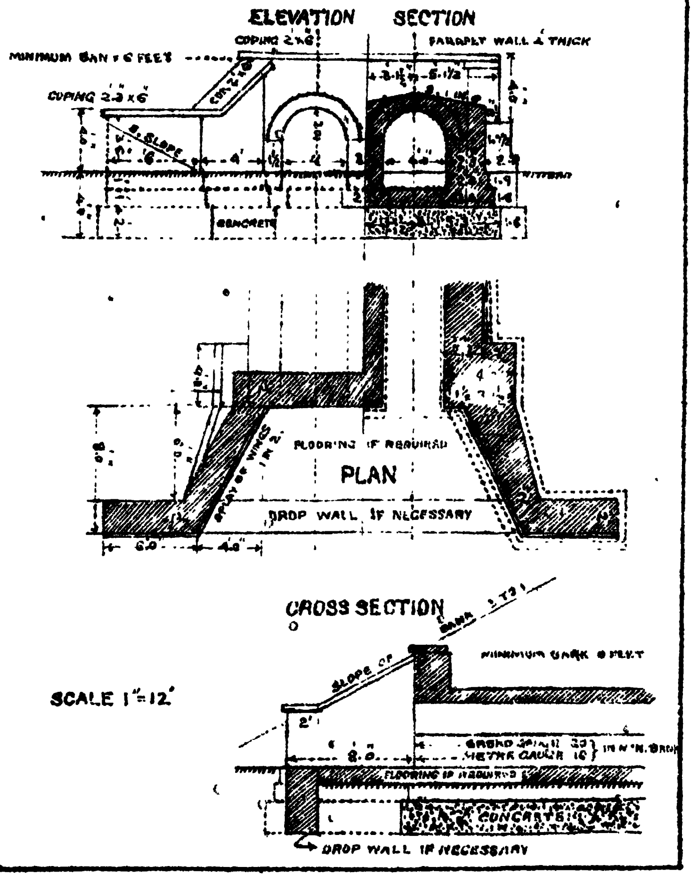
3 FEET SPAN—HEAVY TYPE

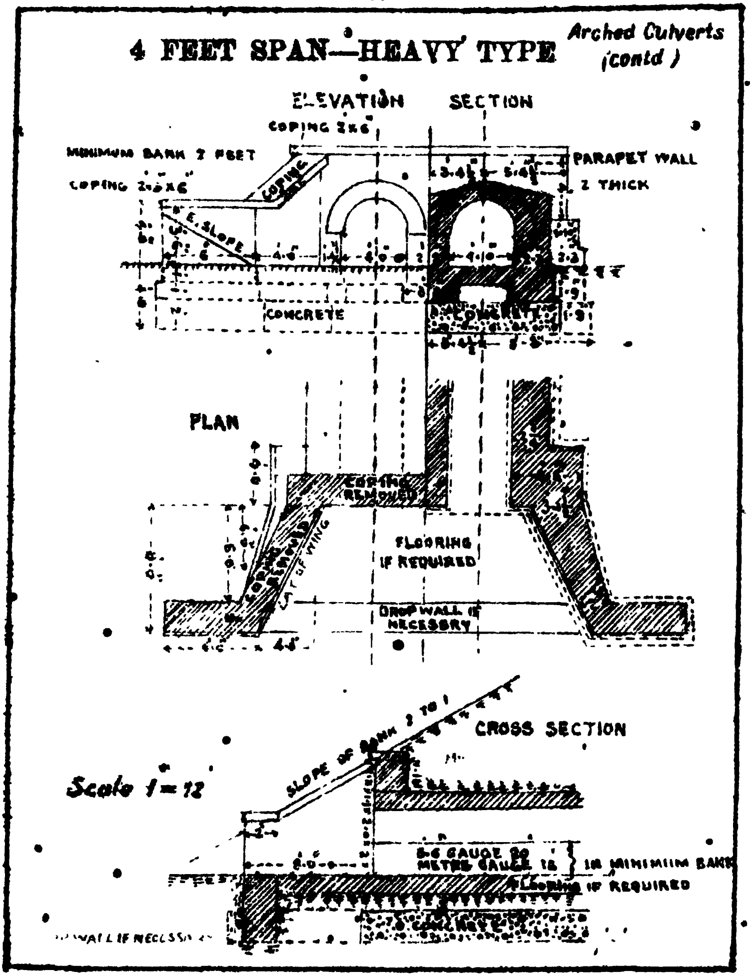
Arched Culverts (contd.)



4 FEET SPAN—LIGHT TYPE.

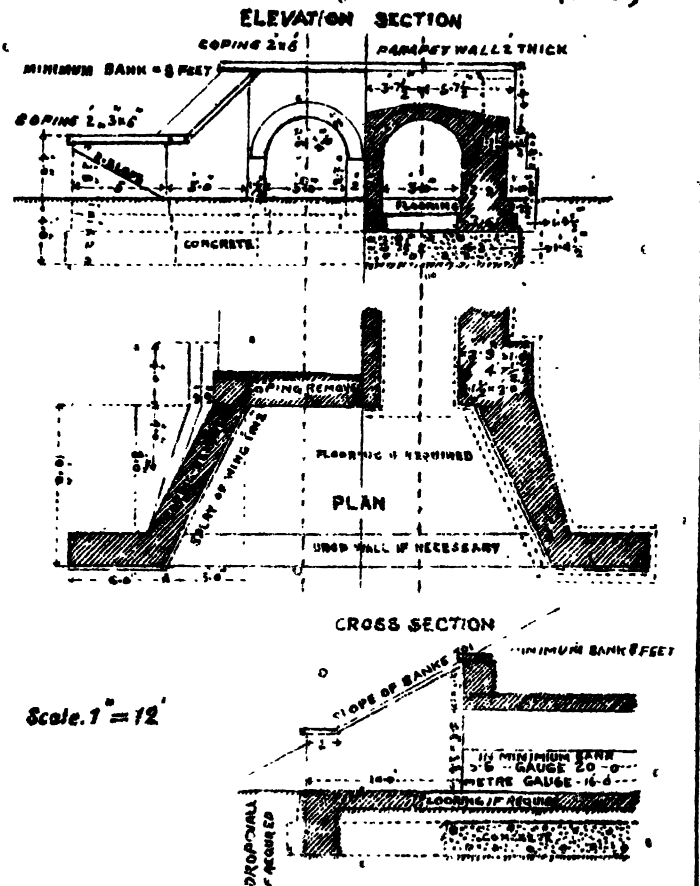
Arched Culverts (contd.)

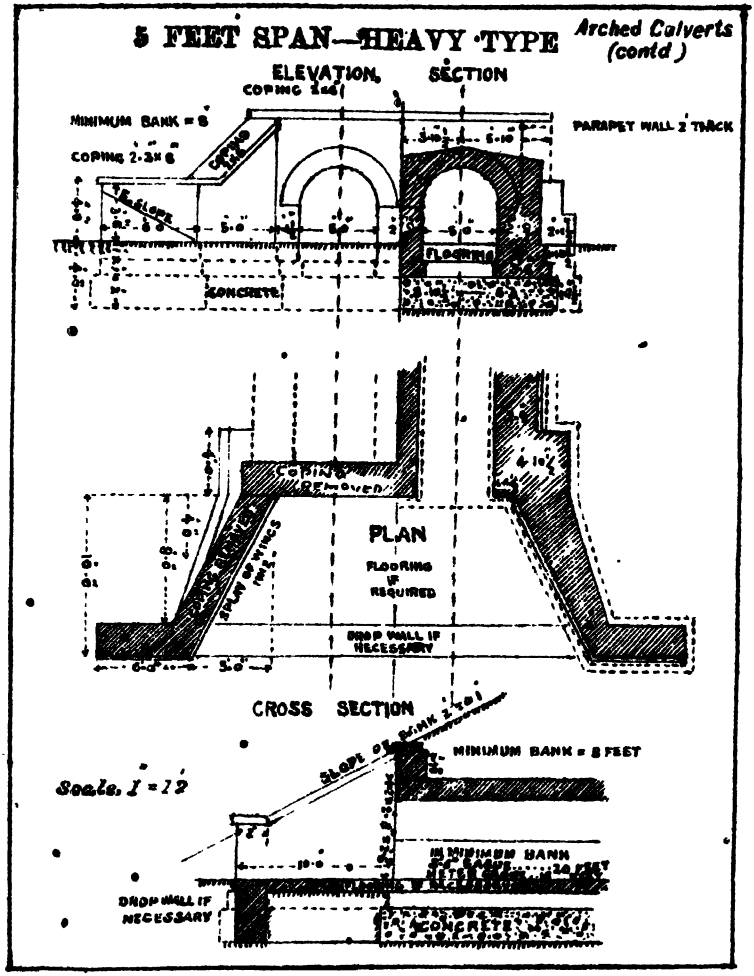



4 FEET SPAN—HEAVY TYPE
Arched Culverts (contd)
ELEVATION
SECTION
COPING
MINIMUM BANK 2 FEET
PARAPET WALL
2 THICK
CONCRETE
PLAN
COPING REMOVED
FLOORING IF REQUIRED
DROP WALL IF NECESSARY
CROSS SECTION
SLOPE OF BANK 2 TO 1
Scale 1"=12'
FLOORING IF REQUIRED
CONCRETE

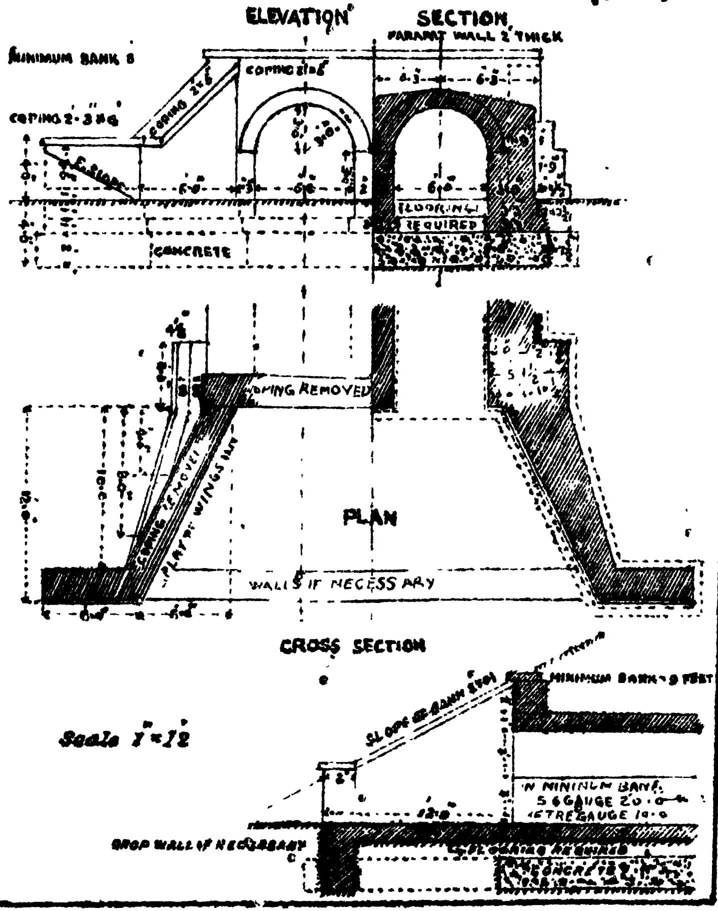
5 FEET SPAN—LIGHT TYPE

Arched Culverts (contd)



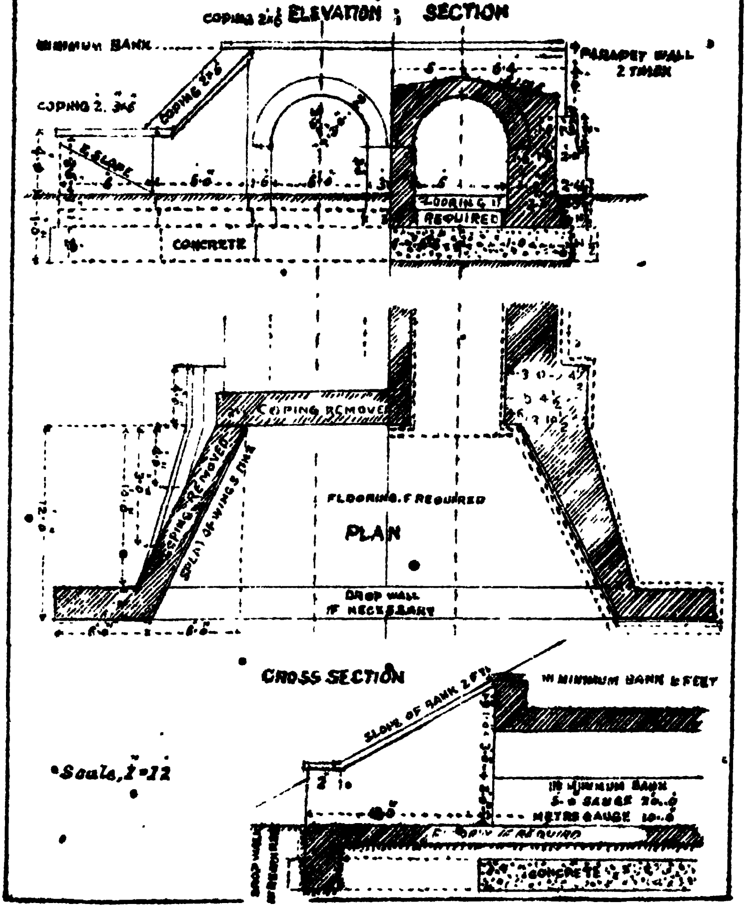

5 FEET SPAN—HEAVY TYPE
Arched Culverts (contd)
ELEVATION
SECTION
MINIMUM BANK = 8'
COPING 2-3 x 6"
PARAPET WALL 2' THICK
FLOORING
CONCRETE
PLAN
COPING REMOVED
FLOORING IF REQUIRED
DROP WALL IF NECESSARY
CROSS SECTION
MINIMUM BANK = 8 FEET
DROP WALL IF NECESSARY
CONCRETE
Scale, 1" = 12'

6 FEET SPAN—LIGHT TYPE



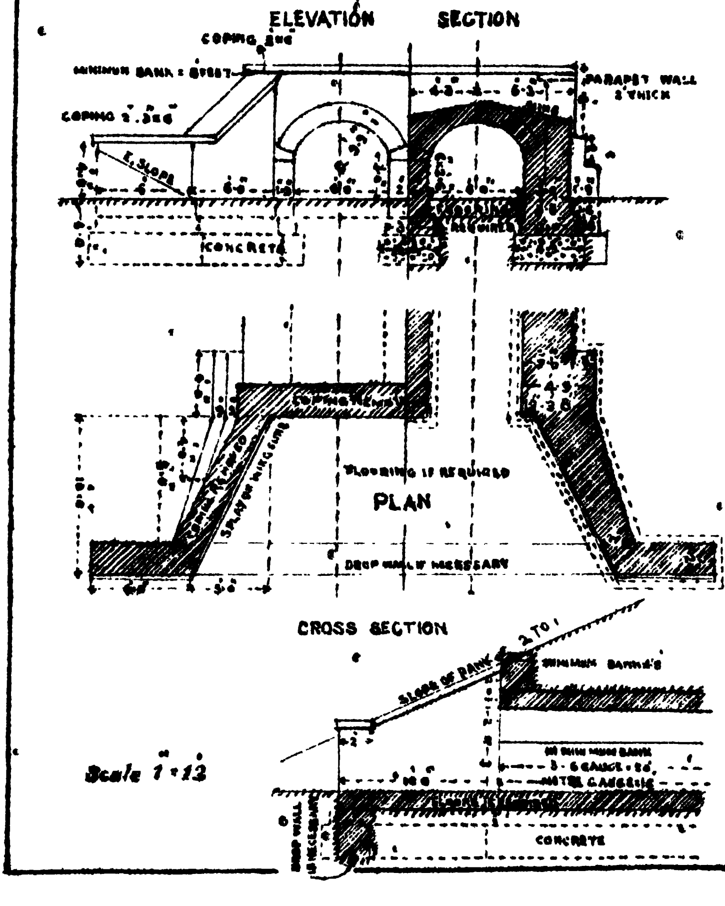
6 FEET SPAN—HEAVY TYPE

Arched Culverts (contd.)



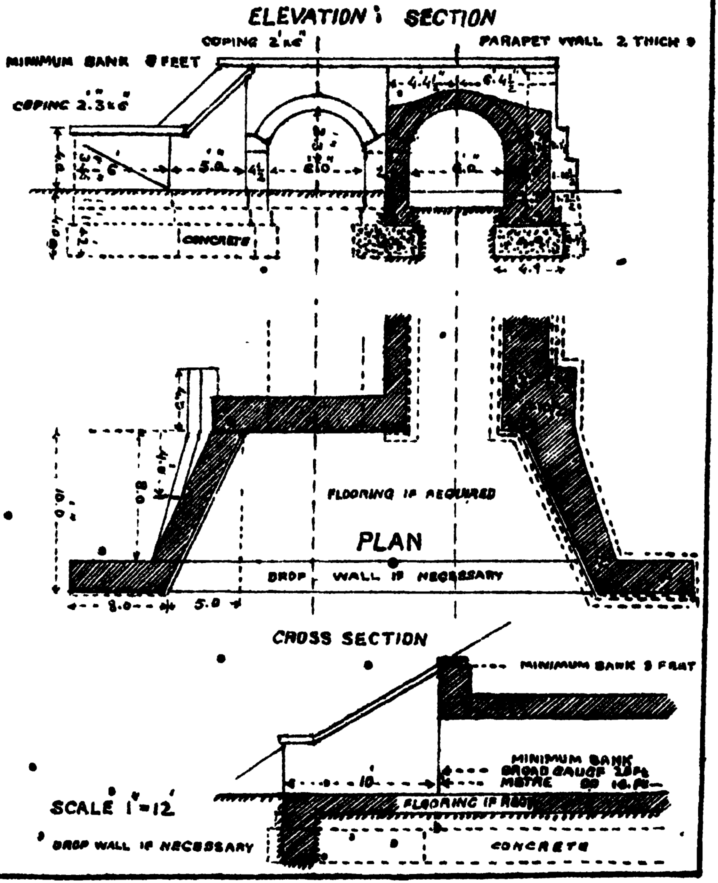
6 FEET SPAN—LIGHT TYPE SEGMENTAL

Arched Culverts (contd.)



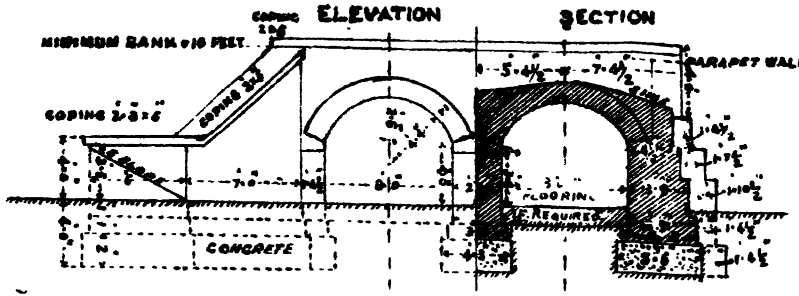
6 FEET SPAN—HEAVY TYPE SEGMENTAL

ARCHED CULVERTS (CONTD)

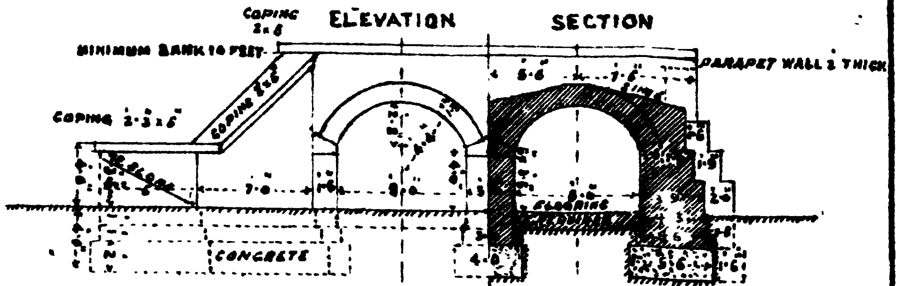


Arched Culverts (contd.)

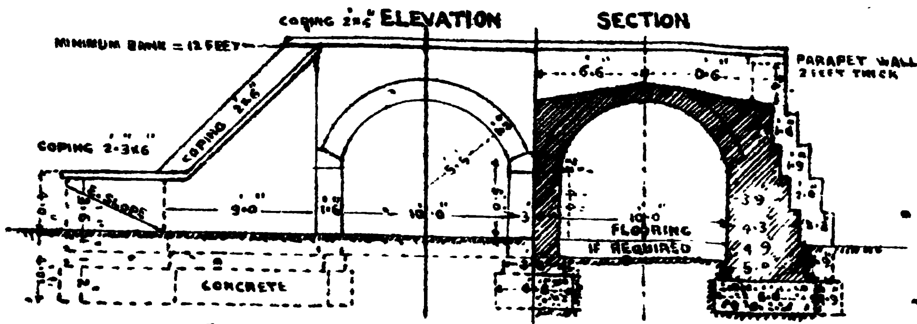
8 FEET SPAN—LIGHT TYPE



8 FEET SPAN—HEAVY TYPE

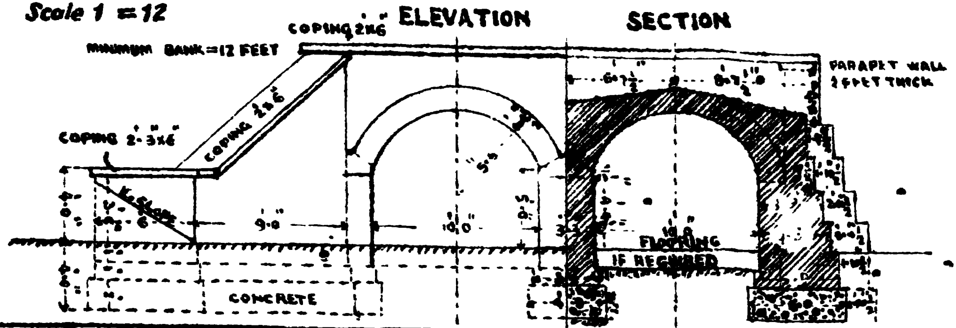


10 FEET SPAN—LIGHT TYPE *Arched Culverts (contd)*



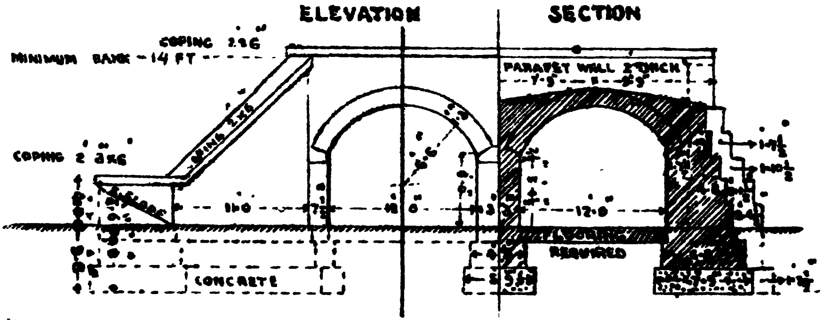
10 FEET SPAN—HEAVY TYPE

Scale 1" = 12"



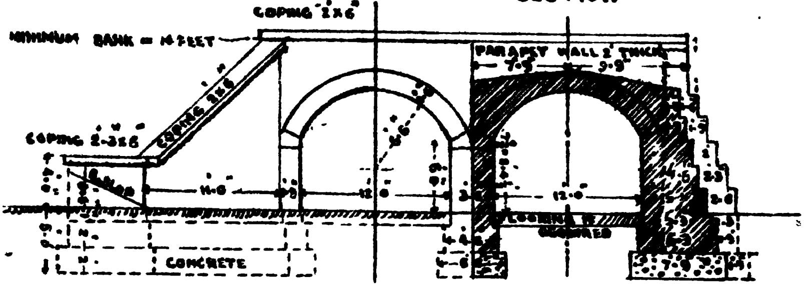
12 FEET SPAN—LIGHT TYPE

Arched Culverts (contd.)



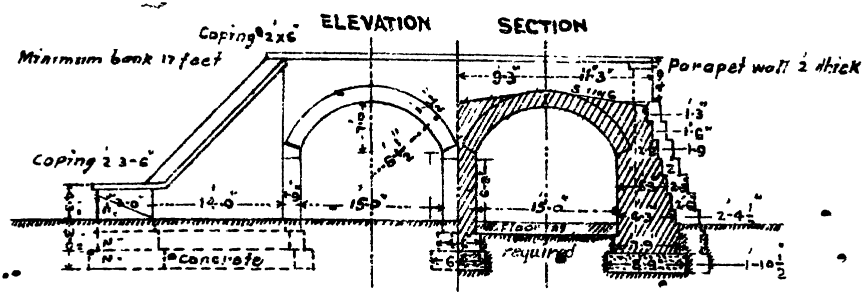
12 FEET SPAN—HEAVY TYPE

Scale 1" = 16'



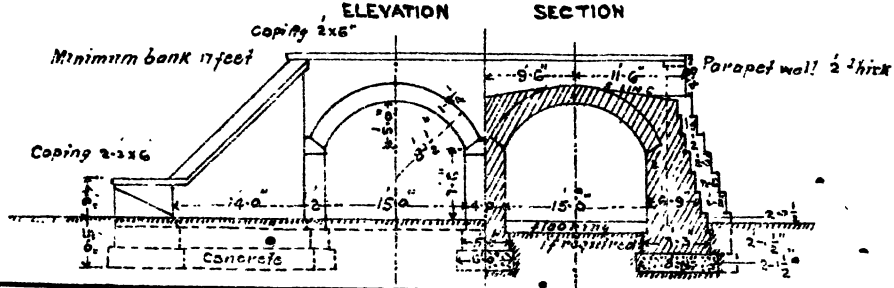
Arched Culverts (Cont.)

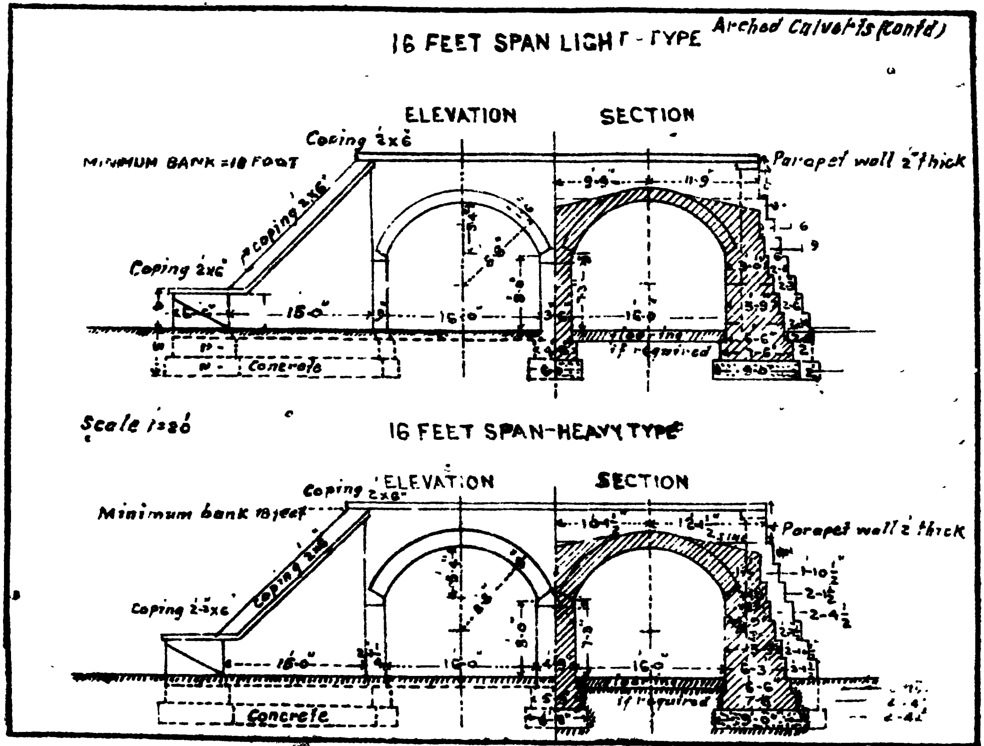
15 FEET SPAN-LIGHT TYPE

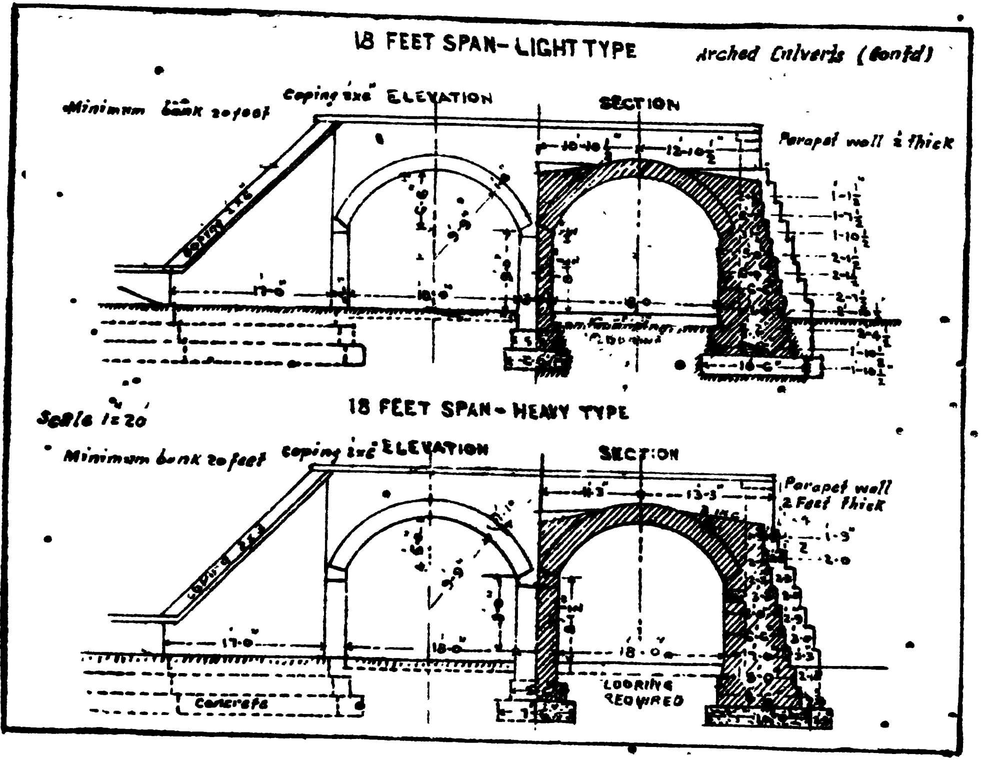


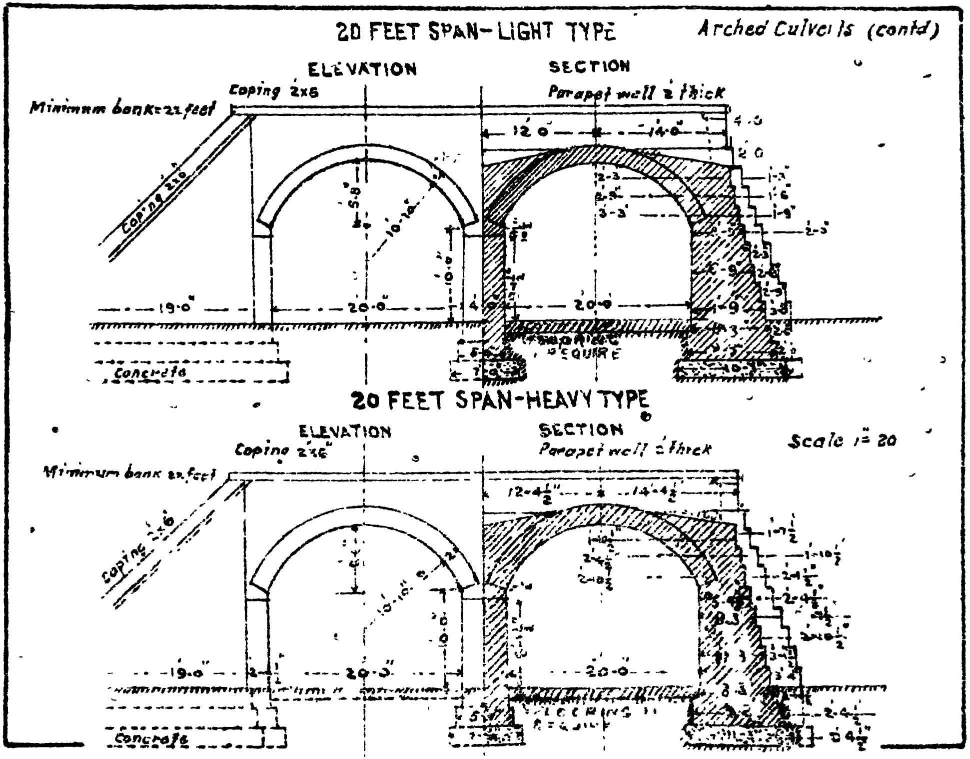
Scale 1" = 20'

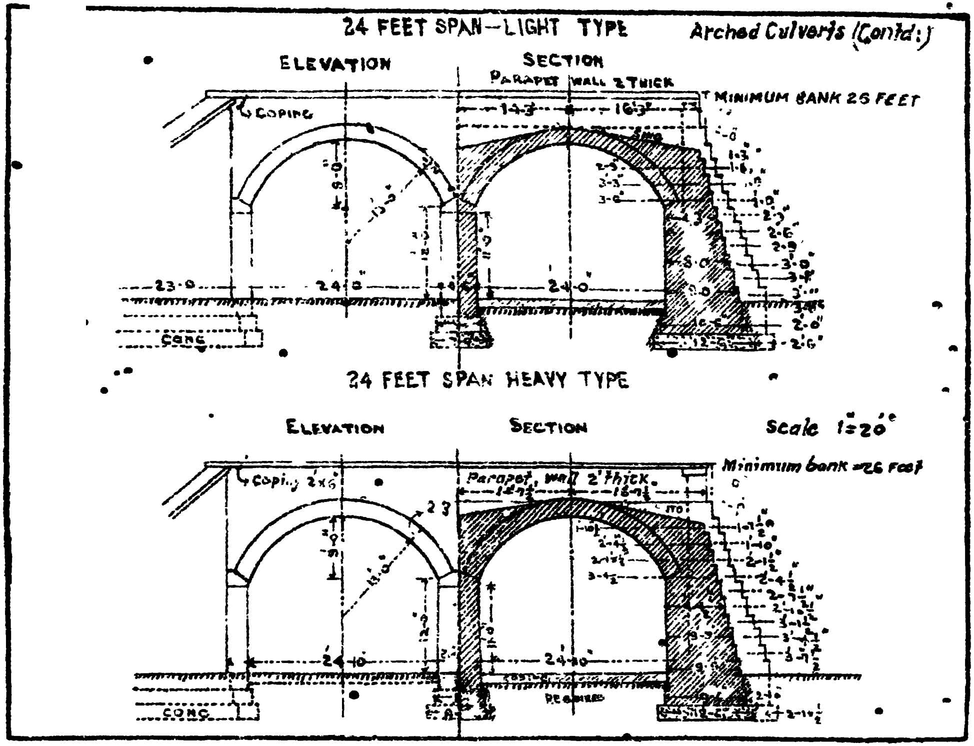
15 FEET SPAN-HEAVY TYPE



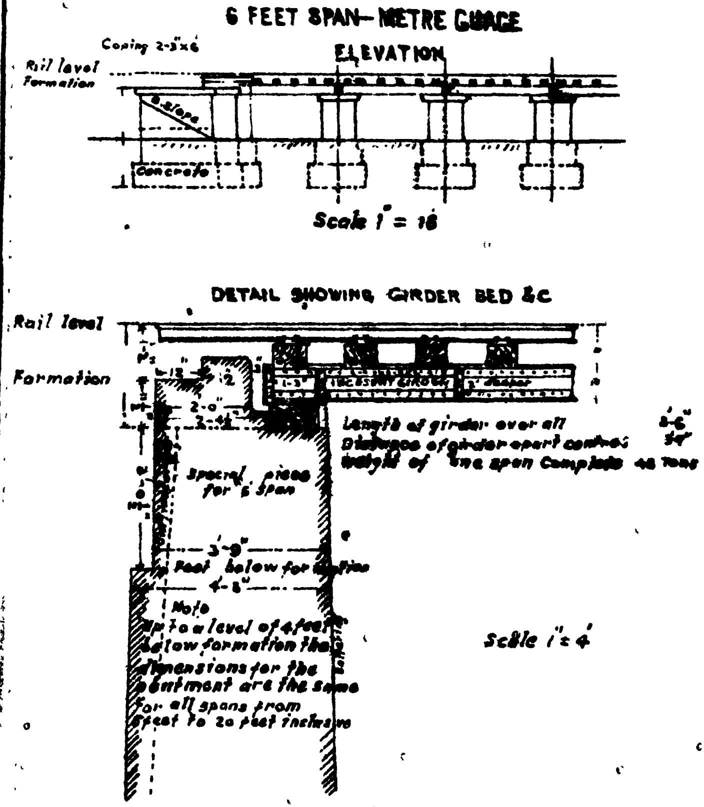

Arched Culverts (Contd)
16 FEET SPAN LIGHT-TYPE
ELEVATION
SECTION
Coping 2"x6"
MINIMUM BANK =18 FOOT
Coping 2"x6"
Coping 2"x6"
Parapet wall 2' thick
Concrete
Footing if required
Scale 1:80
16 FEET SPAN-HEAVY TYPE
ELEVATION
SECTION
Coping 2"x6"
Minimum bank 18 feet
Coping 2"x6"
Coping 2-3"x6
Parapet wall 2' thick
Concrete
Footing if required


18 FEET SPAN-LIGHT TYPE
Arched Culverts (Contd)
Minimum bank 20 feet
Coping 2x6" ELEVATION
SECTION
Parapet wall 1/2 thick
18 FEET SPAN-HEAVY TYPE
Scale 1:20
Minimum bank 20 feet
Coping 2x6" ELEVATION
SECTION
Parapet wall 2 Feet thick
Concrete
LOORING REQUIRED


Arched Culverts (contd)
20 FEET SPAN-LIGHT TYPE
ELEVATION
SECTION
Coping 2x6
Parapet wall 2 thick
Minimum bank=22 feet
Concrete
20 FEET SPAN-HEAVY TYPE
ELEVATION
SECTION
Coping 2x6"
Parapet wall 2 thick
Minimum bank 22 feet
Concrete
Scale 1"= 20


24 FEET SPAN—LIGHT TYPE
Arched Culverts (Contd:)
ELEVATION
SECTION
Parapet wall 2 thick
MINIMUM BANK 25 FEET
Coping
CONC
24 FEET SPAN HEAVY TYPE
ELEVATION
SECTION
Scale 1"=20'
Minimum bank =26 feet
Coping 2'x6"
Parapet, wall 2' thick
CONC

TYPES OF GIRDER BRIDGES SMALL SPANS

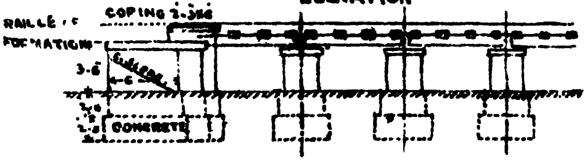


Girder Bridges (contd.)

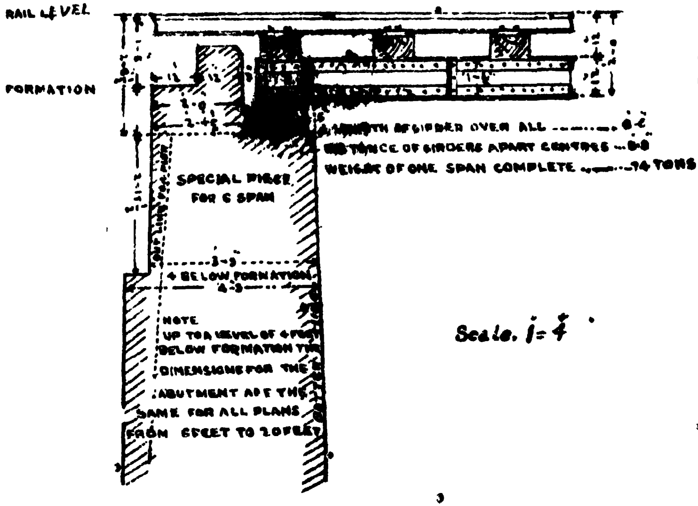
6 FEET SPAN - 5-6" GUAGE

Scale 1" = 16'

ELEVATION



DETAIL SHOWING GIRDER BED. & C.

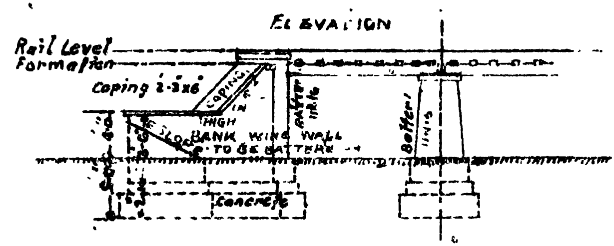


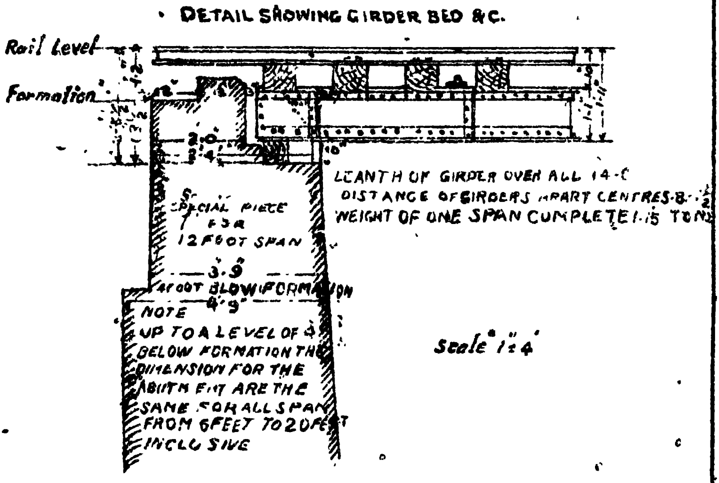
Scale. 1" = 4'

Girder Bridge (contd)

12 FEET SPAN METRE GUAGE

Scale 1"=16'

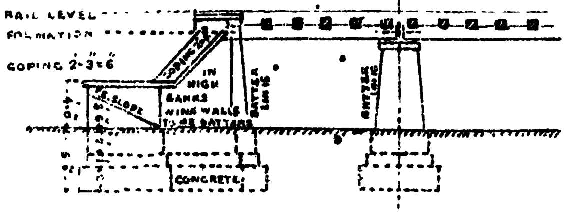




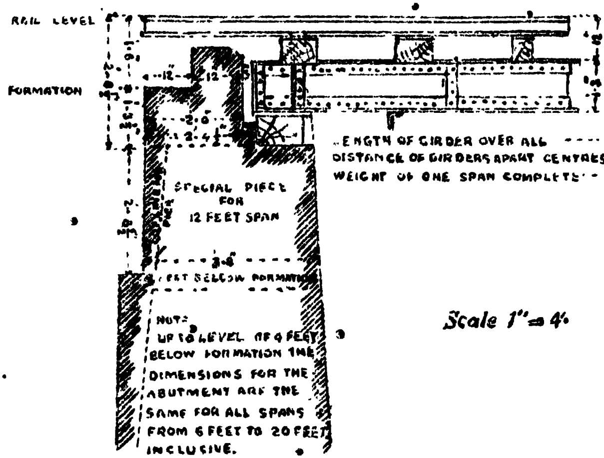
Girder Bridges (contd.)

12 FEET SPAN—5'-6" GUAGE
Scale 1" = 16'

ELEVATION



DETAIL SHOWING GIRDER BED, &c.



LENGTH OF GIRDER OVER ALL ---- 14-6

DISTANCE OF GIRDERS APART CENTRES ---- 5-9"

WEIGHT OF ONE SPAN COMPLETE ---- 1·44 TONS

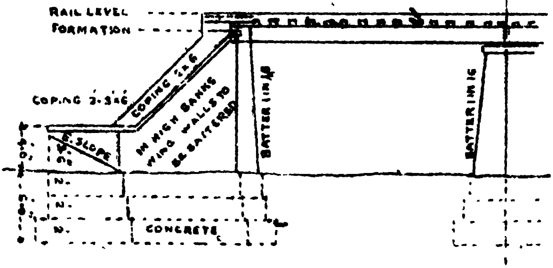
Scale 1" = 4'

Girder Bridges (contd.)

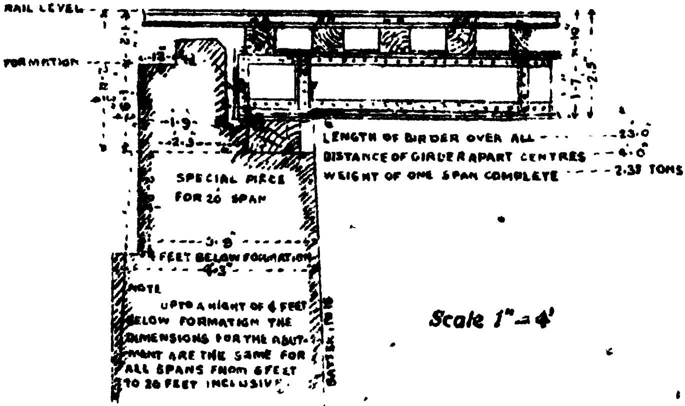
20 FEET SPAN—METRE GUAGE

Scale 1" = 16'

ELEVATION



DETAIL SHOWING GIRDER BED &c.



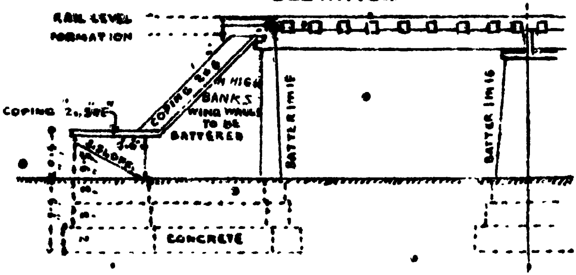
Scale 1" = 4'

Girder Bridges (contd.)

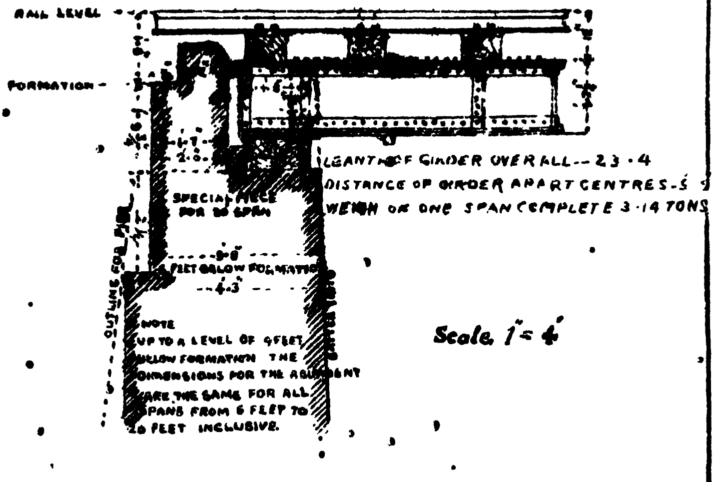
20 FEET SPAN—5'-6" GUAGE

Scale 1"=16'

ELEVATION



DETAIL SHOWING GIRDER BED, &c.



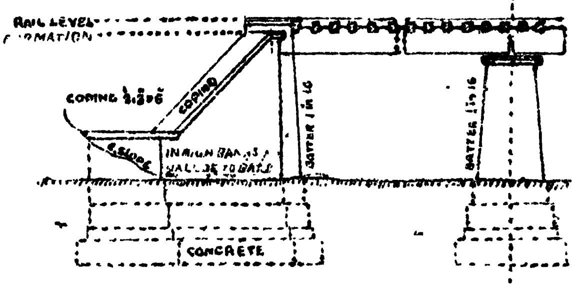
Scale 1"=4'

Girder Bridges (contd)

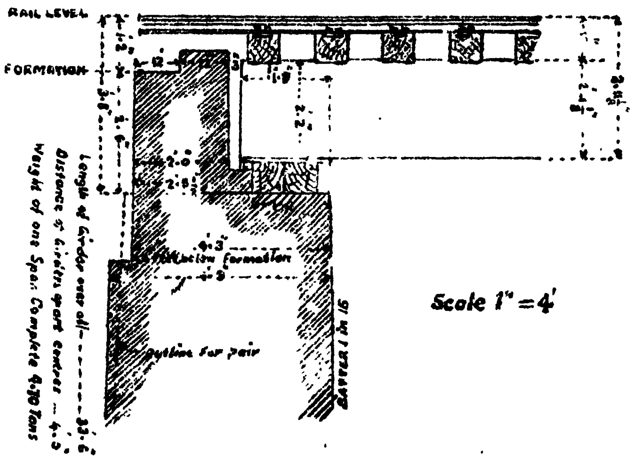
30 FEET SPAN—METRE GUAGE

Scale 1" = 16'

ELEVATION



DETAIL SHOWING GIRDER BED, &c.

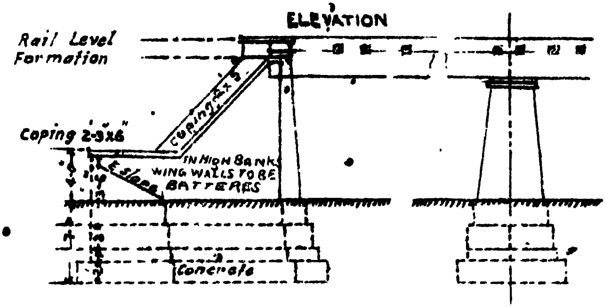


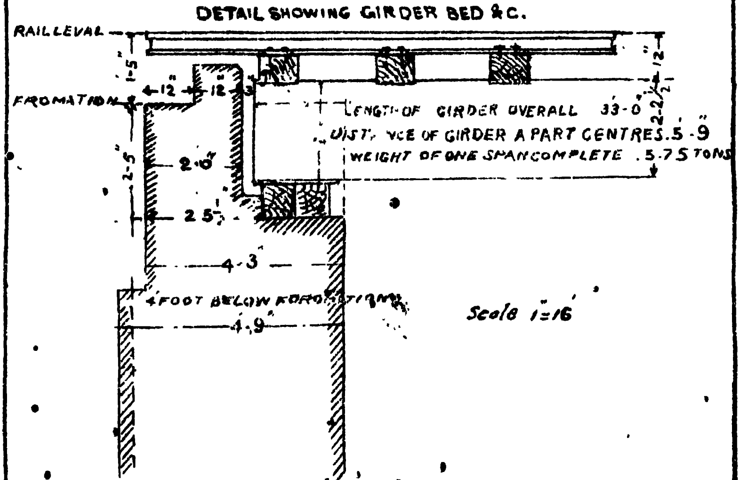
Scale 1" = 4'

Girder Bridge (contd.)

30 FEET SPAN–5'-6" GAUGE

Scale 1"= 16'



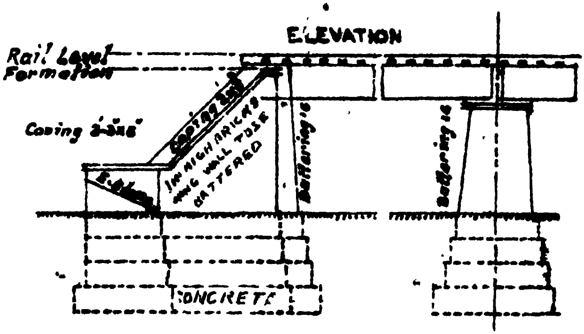


Girder Bridges (contd)

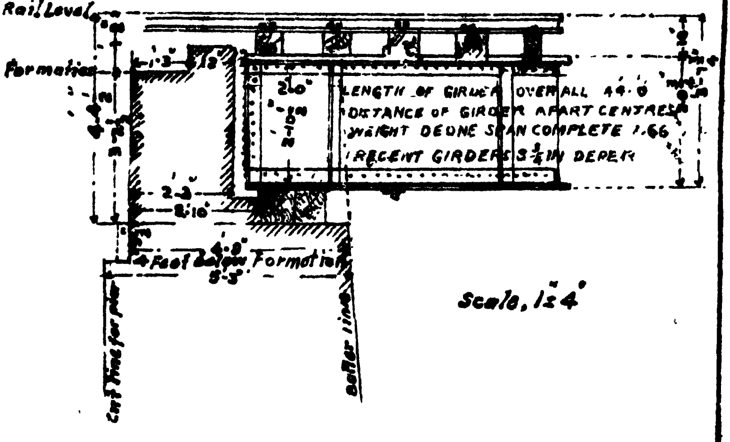
40 FEET SPAN – METRE GAUGE

Scale 1" = 16'

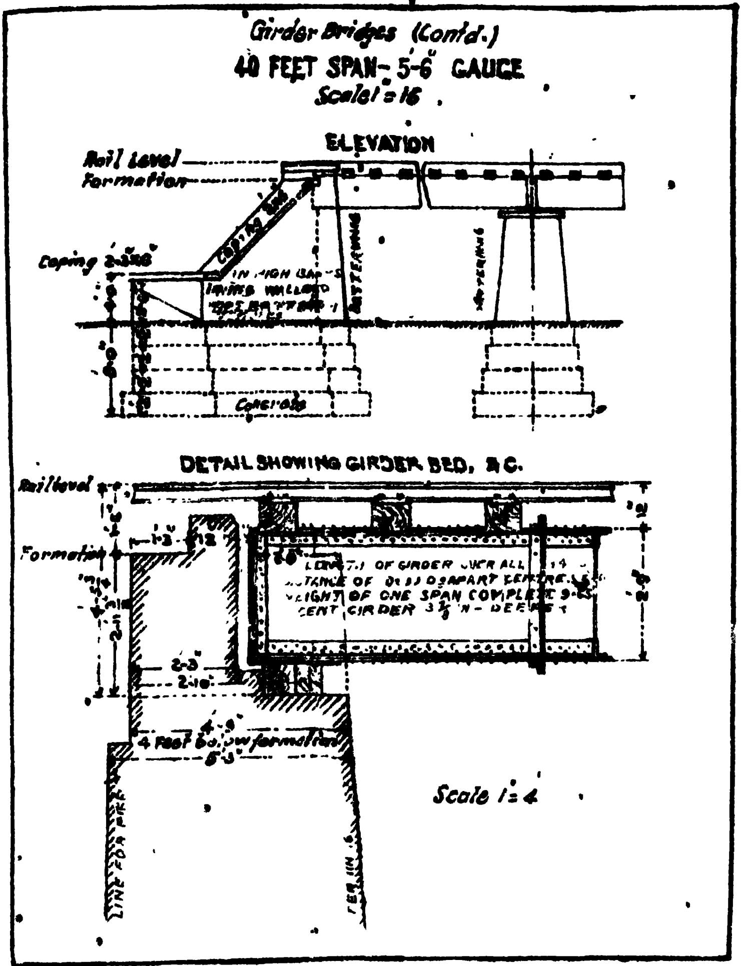
ELEVATION

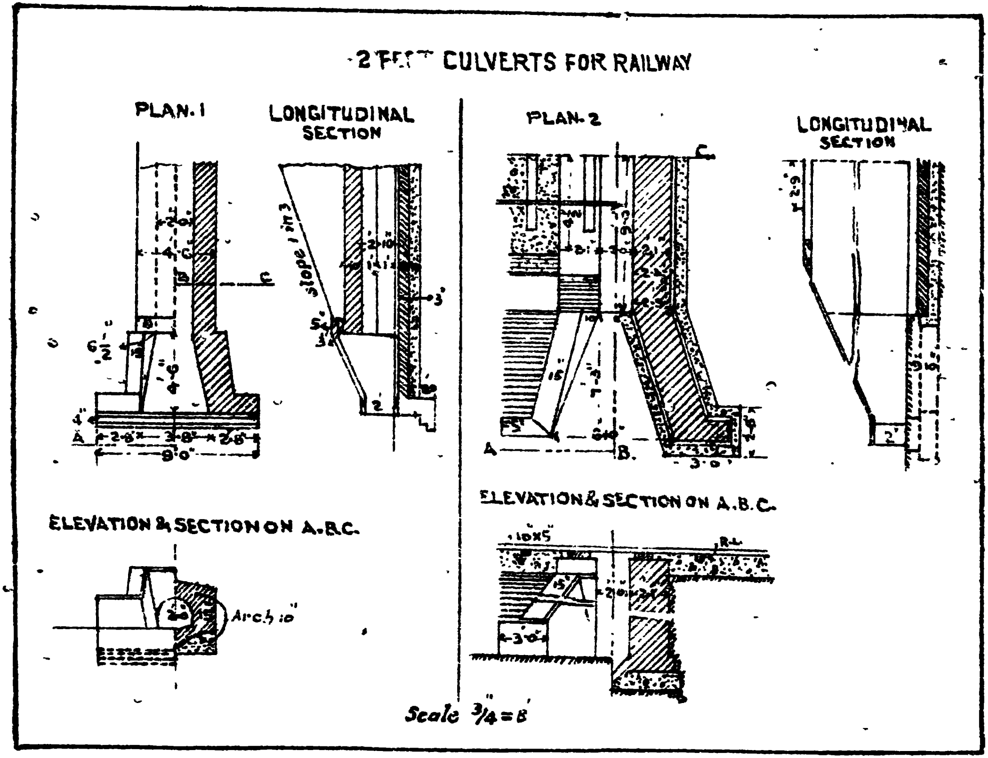


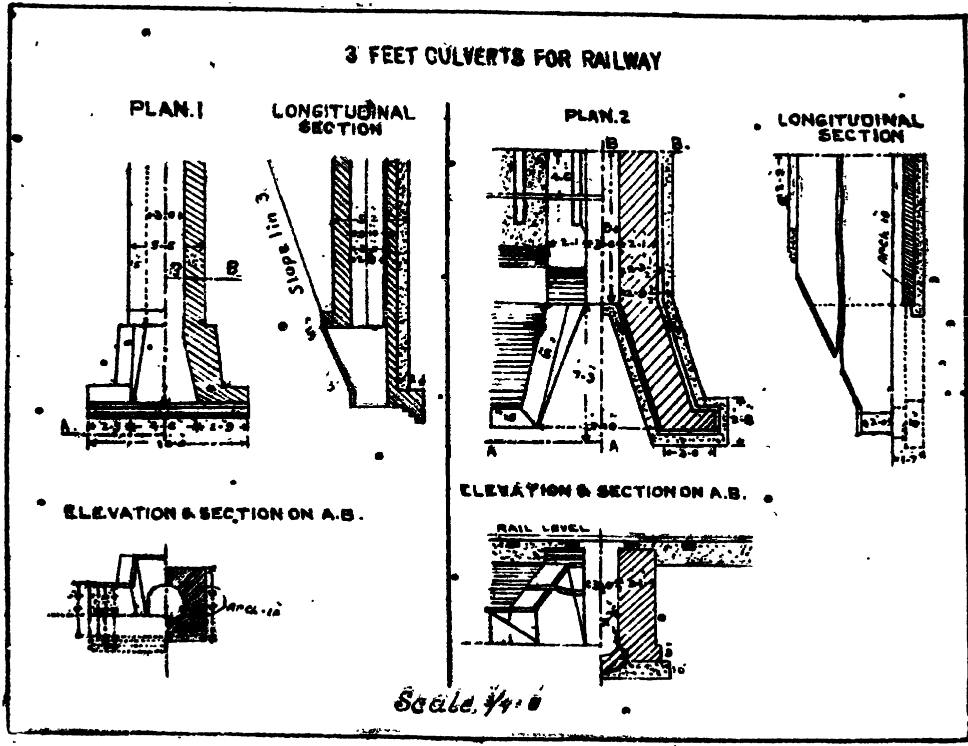
DETAIL SHOWING GIRDER BED, &C

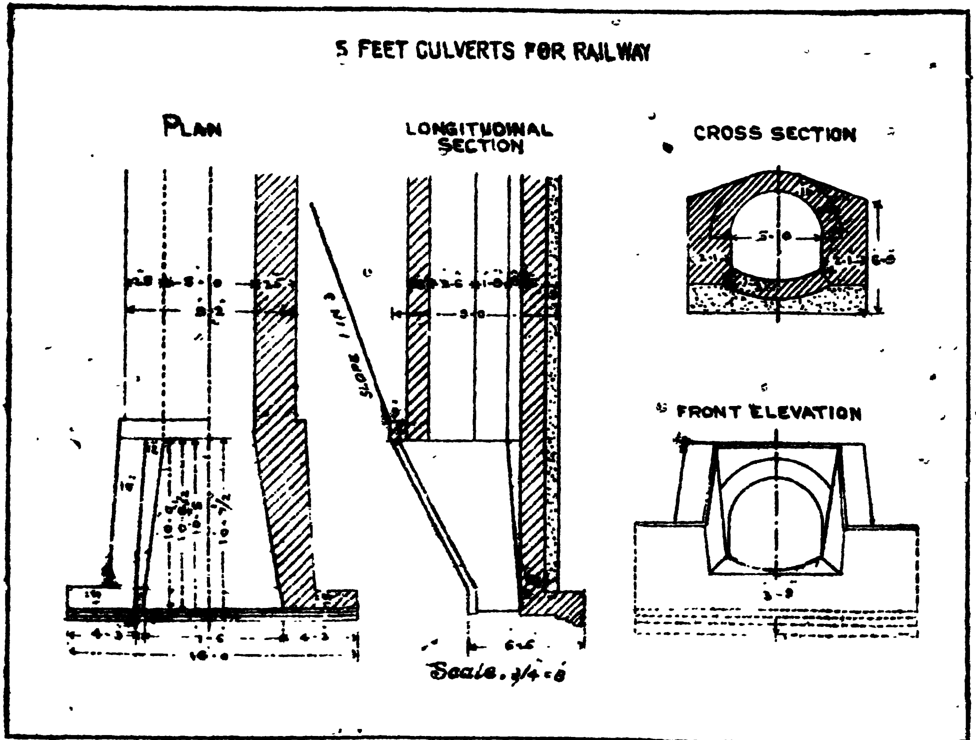


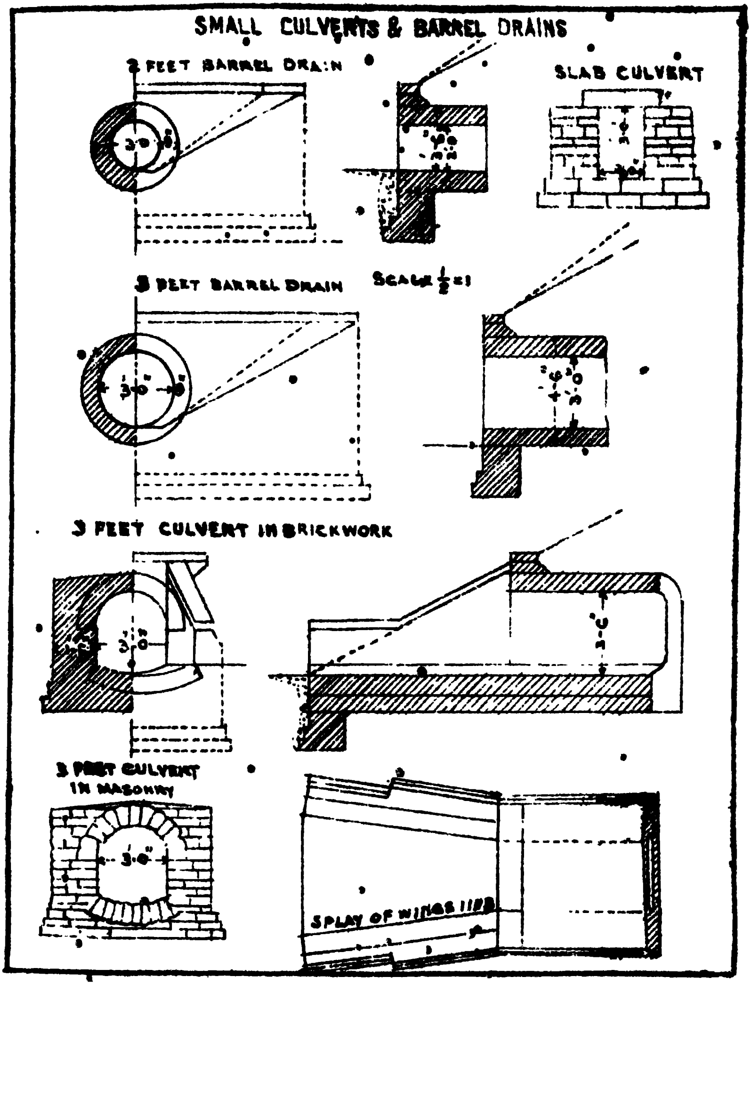
Scale, 1" = 4'


Girder Bridges (Contd.)
40 FEET SPAN – 5'-6" GAUGE
Scale 1" = 16'
ELEVATION
Rail Level
Formation
Coping
Concrete
DETAIL SHOWING GIRDER BED, &C.
Rail level
Formation
4 Feet below formation
Scale 1" = 4'


2 FEET CULVERTS FOR RAILWAY
PLAN. 1
LONGITUDINAL SECTION
slope 1 in 3
ELEVATION & SECTION ON A.B.C.
Arch 10"
PLAN. 2
LONGITUDINAL SECTION
ELEVATION & SECTION ON A.B.C.
Scale 3/4" = 8'


3 FEET CULVERTS FOR RAILWAY
PLAN.1
LONGITUDINAL SECTION
Slope 1 in 3
ELEVATION & SECTION ON A.B.
PLAN.2
LONGITUDINAL SECTION
ELEVATION & SECTION ON A.B.
RAIL LEVEL
Scale 1/4 : 1

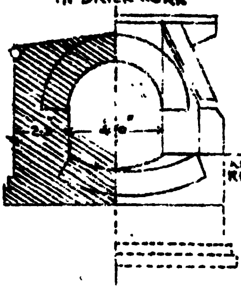

5 FEET CULVERTS FOR RAILWAY
PLAN
LONGITUDINAL SECTION
CROSS SECTION
FRONT ELEVATION
SLOPE 1 IN 3
5·0
6·6
3·0
16·0
4·3
7·6
6·6
3·9
Scale. 3/4 = 8

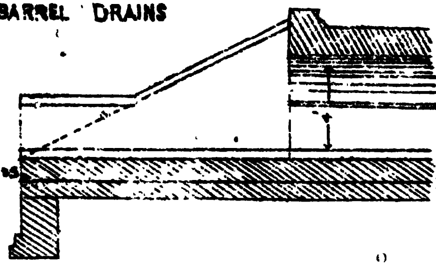

SMALL CULVERTS & BARREL DRAINS
2 FEET BARREL DRAIN
SLAB CULVERT
3 FEET BARREL DRAIN
SCALE ½ = 1
3 FEET CULVERT IN BRICKWORK
3 FEET CULVERT IN MASONRY
3'-0"
SPLAY OF WINGS 1 IN 8

SMALL CULVERTS & BARREL DRAINS

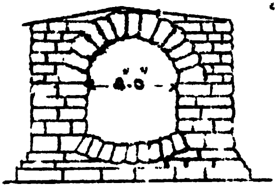
Scale 1/8"=1'

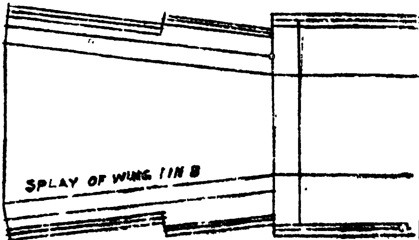
4 FEET CULVERT IN BRICK WORK





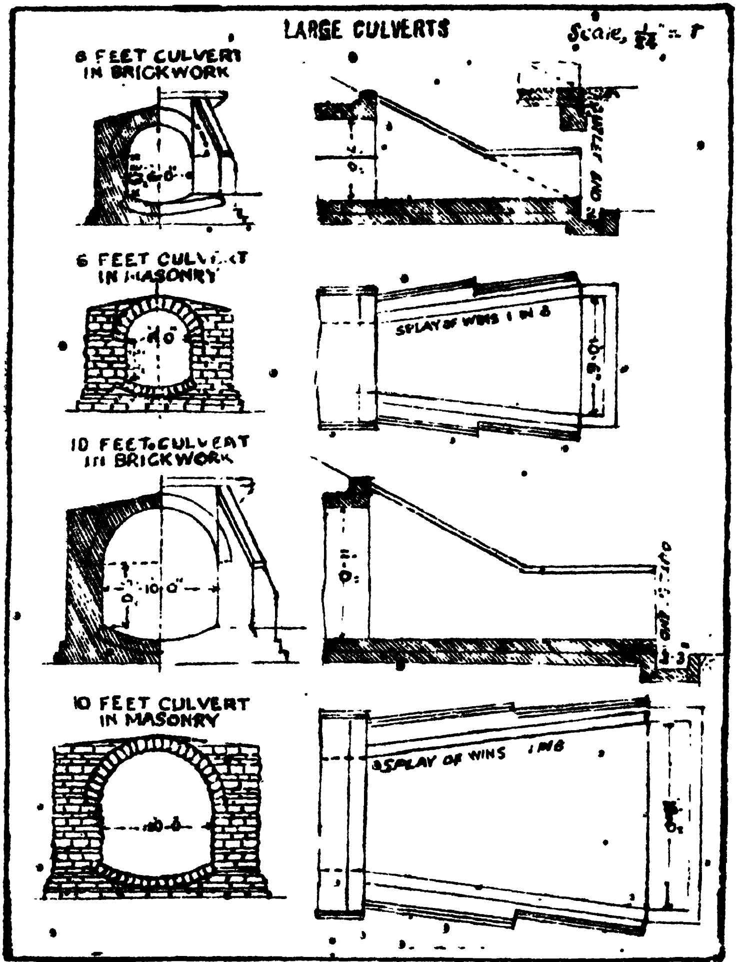
4 FEET CULVERT IN MASONRY





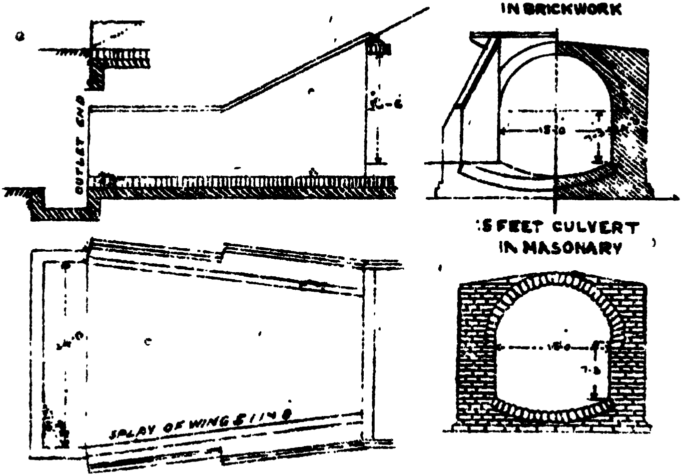
	2' Barrel Brickwork	2' Barrel Brickwork.	3' Barrel Masonry.	3' Barrel Masonry.	3' Culvert Masonry	4' Culvert Brickwork	4' Culvert Masonry.
Thickness of arch	0-9"	0-9"	0-9"	0-9"	0-10"	0-13½"	0-14"
,, ,, Invert				0-9"	0-10"	0-9"	0-10"
,, ,, Sides	2-0"			1-9"	2-0"	2-3"	2-6"
Radius of Invert		1-0"	1-6"	3-6"	3-6"	4-6"	4-6"
Clear depth insides	3-3"	2-0"	3-0"	3-6"	4-6"	4-4"	4-9"
Minimum Summered joint					0-9"		1-6"
Contents of 1 ft. length Cub. ft	21-2"	[illegible]-48	5-24	23-0	33-0"	43-0"	48-0"

Clinkers broken bats, and Kiln refuse should be thrown down as a protection against scour at the outlet end of each culvert.

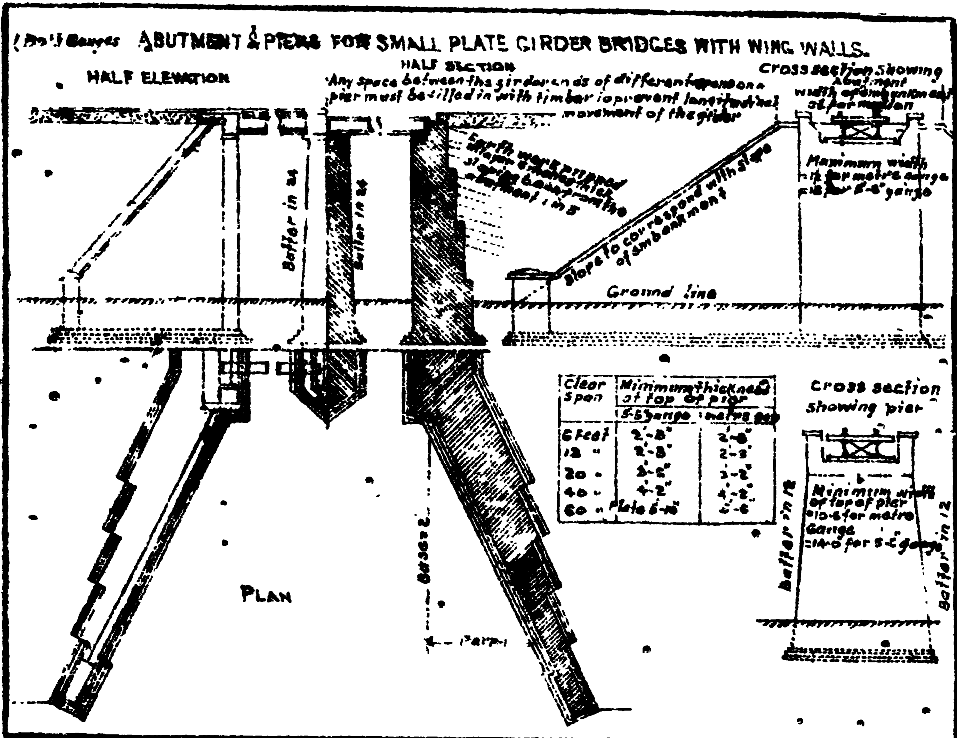

LARGE CULVERTS
Scale,
8 FEET CULVERT IN BRICKWORK
6 FEET CULVERT IN MASONRY
SPLAY OF WINS 1 IN 8
10 FEET CULVERT IN BRICKWORK
10 FEET CULVERT IN MASONRY
SPLAY OF WINS 1 IN 8

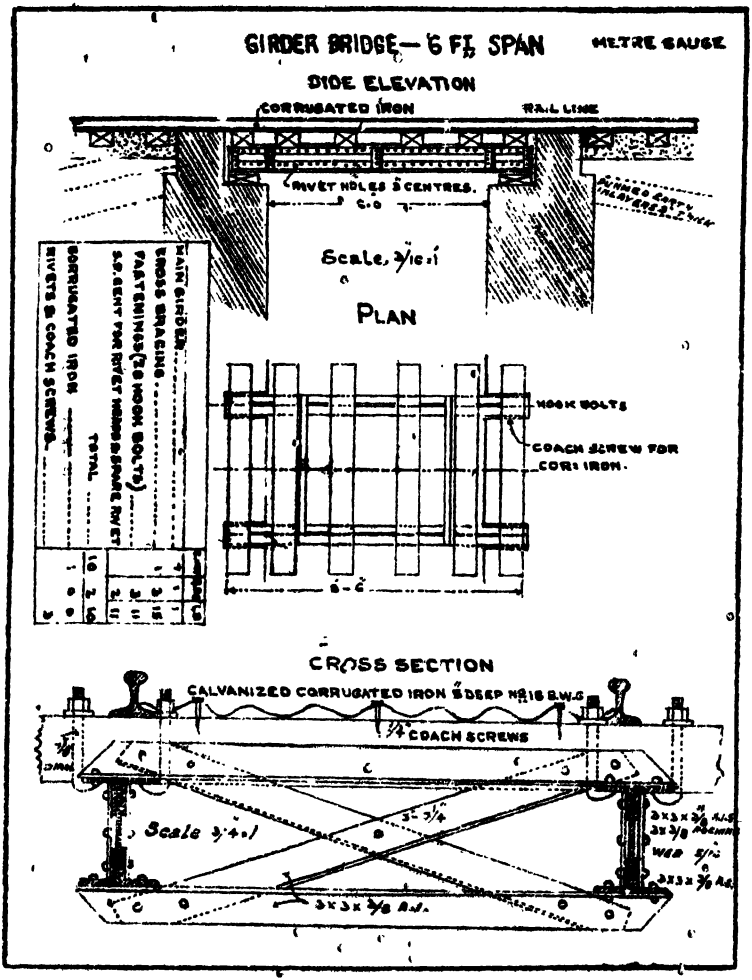
LARGE CULVERTS

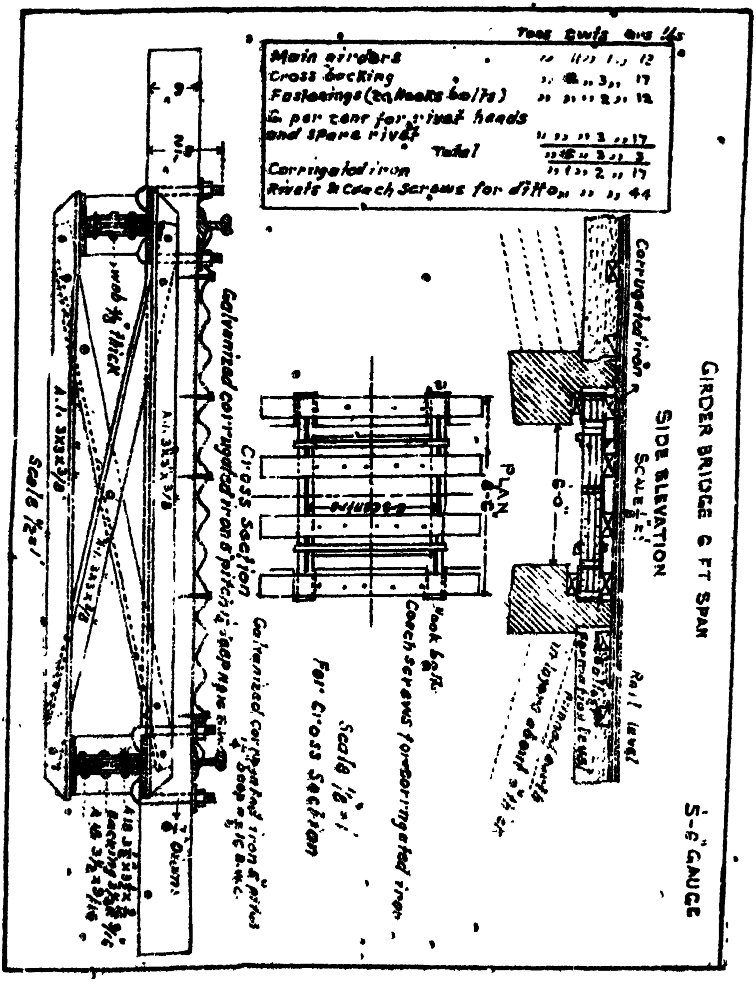
Scale 1/4"-1'



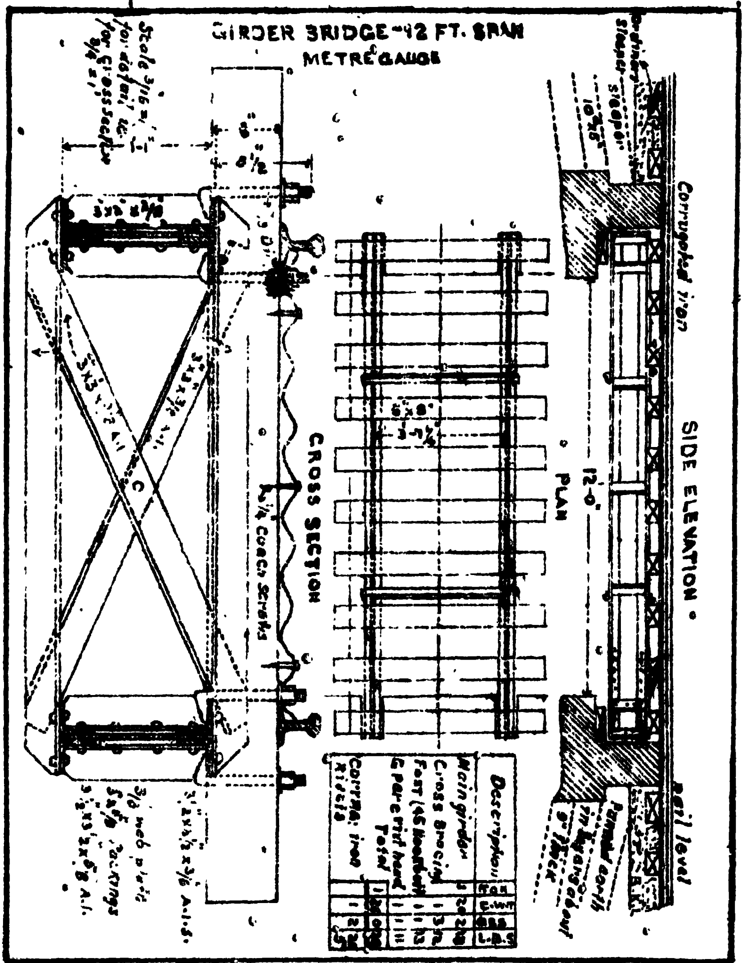
	6' Culvert		10' Culvert.		15' Culvert	
	Brickwork	Masonry	Brickwork	Masonry	Brickwork	Masonry
Thickness of Arch	1-1½	1-3	1-1½	1-6	1-6	1-6
" " Invert	0-9	1-0	1-1½	1-2	1-1½	1-2
" " Sides	2-6	3-0	3-6	4-0	4-3	4-9
Radius of Invert	6-4½	6-4½	13-0	13-0	16-11⅝	16-11⅝
Clear Depth Inside	7-6	7-0	11-0	11-0	15-6	16-6
Minimum Summered Joint	...	1-0	...	1-2	...	1-2
Contents of 1 Ft. Length Cub Ft.	69	83	144	16-2	256	290


ABUTMENT & PIERS FOR SMALL PLATE GIRDER BRIDGES WITH WING WALLS.
HALF ELEVATION
HALF SECTION
Any space between the girder ends of different spans on a pier must be filled in with timber to prevent longitudinal movement of the girder
Cross section showing Abutment
Batter in 24
Batter in 24
Slope to correspond with slope of embankment
Ground line
Clear Span
Minimum thickness at top of pier
5-6" gauge
metre gauge
6 Feet 2'-8" 2'-8"
12 " 2'-8" 2'-3"
20 " 3'-6" 3'-2"
40 " 4'-2" 4'-2"
60 " Plate 5'-10"
Cross section showing pier
Batter in 12
Batter in 12
PLAN
Base = 2

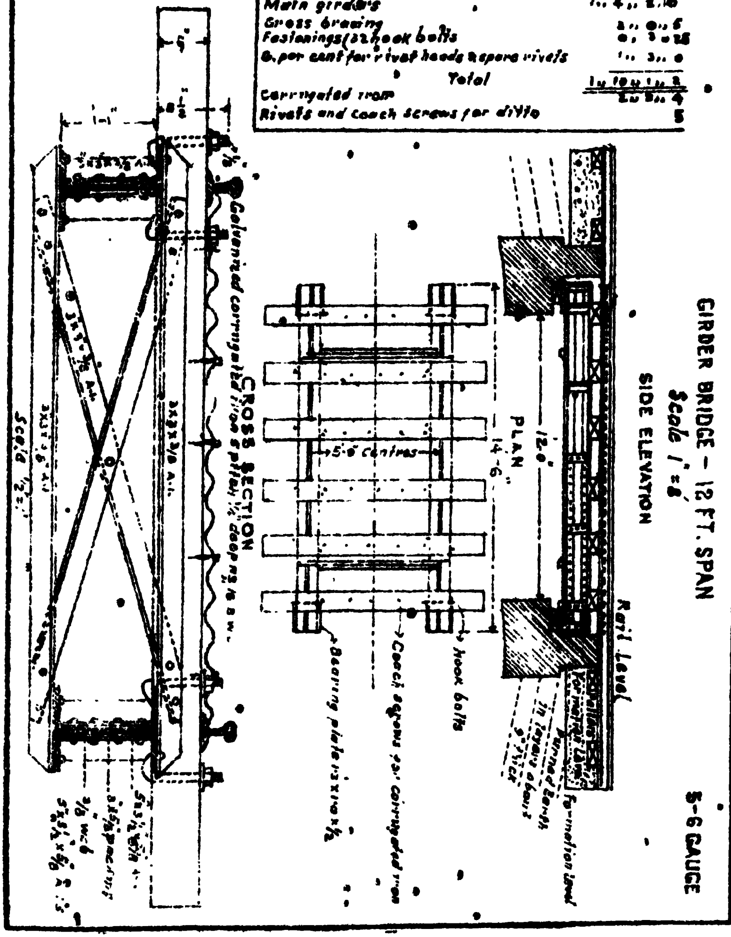

GIRDER BRIDGE — 6 FT. SPAN
METRE GAUGE
SIDE ELEVATION
CORRUGATED IRON
RAIL LINE
RIVET HOLES 3" CENTRES.
Scale, 3/16:1
PLAN
HOOK BOLTS
COACH SCREW FOR CORR. IRON.
MAIN GIRDER
CROSS BRACING
FASTENINGS (28 HOOK BOLTS)
CORRUGATED IRON
RIVETS & COACH SCREWS
TOTAL
CROSS SECTION
GALVANIZED CORRUGATED IRON
3/4" COACH SCREWS
Scale 3/4:1

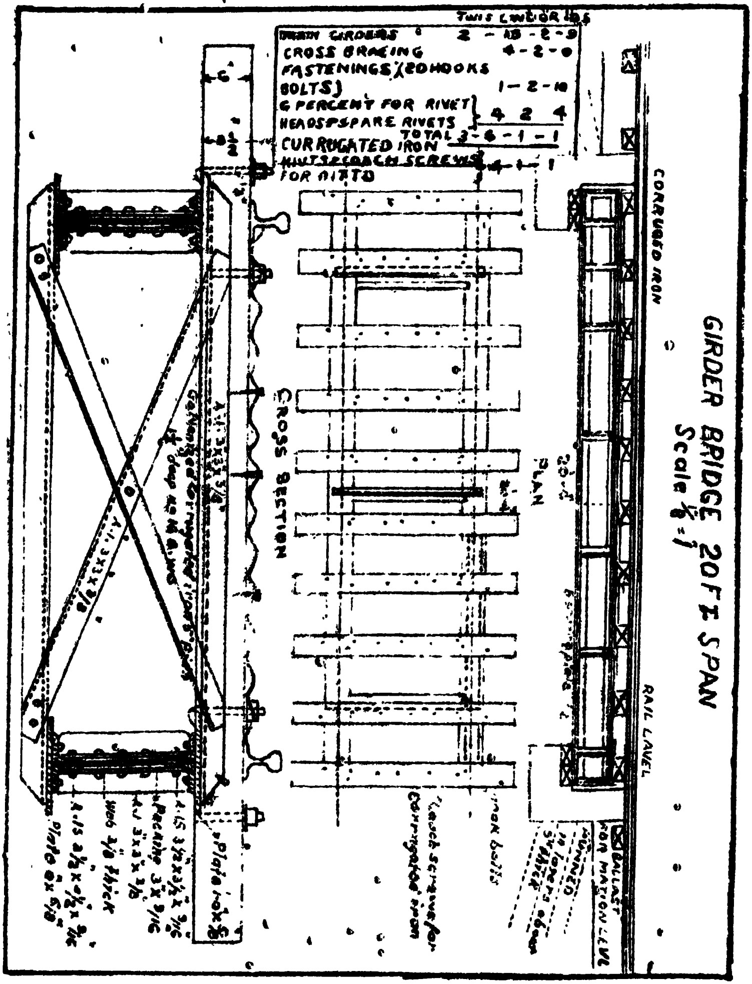

Tons Cwts qrs lbs
Main girders
Cross backing
Fastenings (hooks bolts)
per cent for rivet heads and spare rivets
Total
Corrugated iron
Rivets & Coach Screws for ditto
GIRDER BRIDGE 6 FT SPAN
SIDE ELEVATION
5'-6" GAUGE
Corrugated iron
Rail level
PLAN
6'-0"
Cross Section
Hook bolt
Coach screws for corrugated iron
Galvanized corrugated iron 5" pitch
Scale 1/2"=1'
For Cross Section
web 3/8" thick
Scale 1/2"=1'

GIRDER BRIDGE—12 FT. SPAN
METRE GAUGE

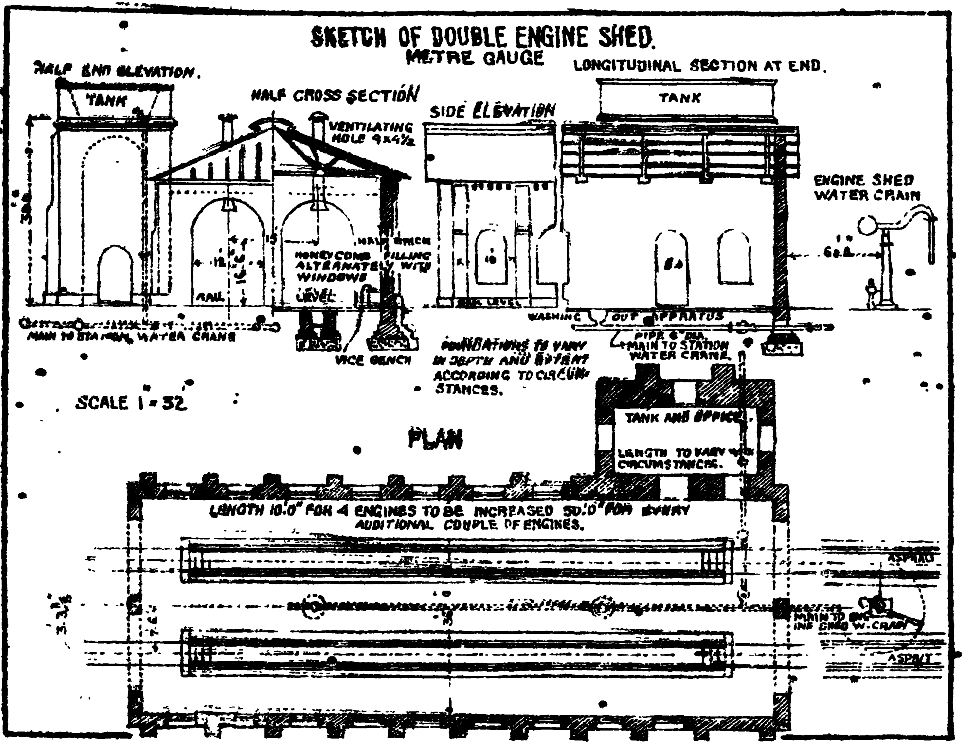


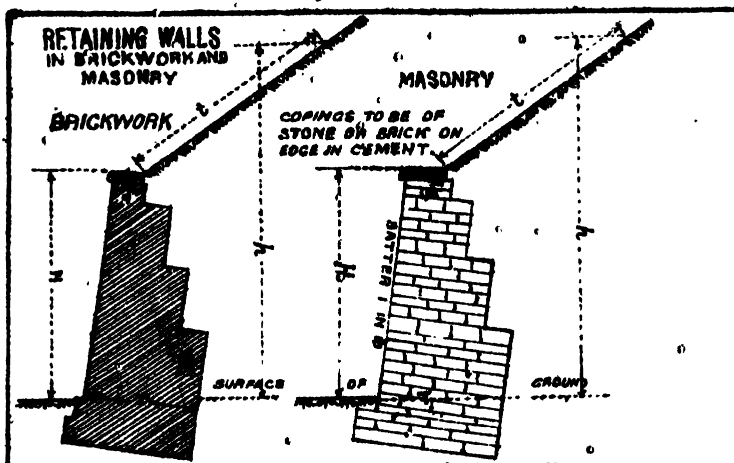
	Ton cwt qrs lbs
Main girders	1,, 4,, 2,, 10
Cross bracing	2,, 0,, 6
Fastenings (32 hook bolts	0,, 3 ,, 25
0 per cent for rivet heads & spare rivets	1,, 3,, 0
Total	1,, 10,, 1,, 2
Corrugated iron	2,, 3,, 4
Rivets and coach screws for ditto	5





GIRDER BRIDGE 20 FT SPAN
Scale ⅛ = 1
CROSS BRACING 4-2-0
FASTENINGS (20 HOOKS BOLTS) 1-2-10
6 PERCENT FOR RIVET HEADS & SPARE RIVETS 4 2 4
TOTAL 3-6-1-1
CURRUGATED IRON
CROSS SECTION
PLAN
CORRUGATED IRON
RAIL LAVEL
BALLAST
FOR MATION LEVL
Hook bolts
Web 3/8" thick


SKETCH OF DOUBLE ENGINE SHED.
METRE GAUGE
HALF END ELEVATION.
TANK
HALF CROSS SECTION
VENTILATING HOLE 9x4½
HALF BRICK
HONEYCOMB FILLING ALTERNATELY WITH WINDOWS
RAIL
LEVEL
MAIN TO STATION WATER CRANE
VICE BENCH
SIDE ELEVATION
FOUNDATIONS TO VARY IN DEPTH AND EXTENT ACCORDING TO CIRCUMSTANCES.
LONGITUDINAL SECTION AT END.
TANK
WASHING OUT APPARATUS
PIPE 6" DIA. MAIN TO STATION WATER CRANE.
ENGINE SHED WATER CRAIN
SCALE 1"=32'
PLAN
TANK AND OFFICE.
LENGTH TO VARY WITH CIRCUMSTANCES.
LENGTH 10.0" FOR 4 ENGINES TO BE INCREASED 50.0" FOR EVERY ADDITIONAL COUPLE OF ENGINES.
MAIN TO ENGINE SHED W. CRANE
ASPHALT
ASPHALT



Thickness at Base of Retaining Walls

Ordinary

Height in feet H	Values of h			
	A	B	C	D
5	1—6	1-10½	1—9	2—0
10	3—0	3—4½	3—6	3—9
15	4—6	4 10½	5—3	5—6
20	5—7½	6—0	7—0	7—6
25	7—1½	7—6	8—6	9—0
30	8—6	9·0	10—3	10—9
35	9—6	10—0	11—6	12—3
40	10—9	11—6	13—3	14—0
45	11—9	12—6	14—6	15—3
50	12—6	13—6	15—6	16—0
above 60	25 H	27 H	31 H	33 H

Surcharged.

In calculating the thickness of Surcharged walls substitute h for H where h is the perpendicular height from the surface of the ground to the end of a line l=H measured along the slope to be retained by the Surcharged wall on T = L × X; when T.=thickness of Surcharged wall at the base.

t= do. Ordinary do.

x=Multiplier varying with the slope, and is=1·71 for slope of 1 to 1

=1·55 „ „ 1½ to 1

=1·45 „ „ 2 to 1

=1·32 „ „ 3 to 1

=1·24 „ „ 4 to 1

The dotted line at the back of each section denotes the minimum thickness to be given in arranging the offsets. The Footings vary in depth and extend according to the nature of the case and the character of the foundation.

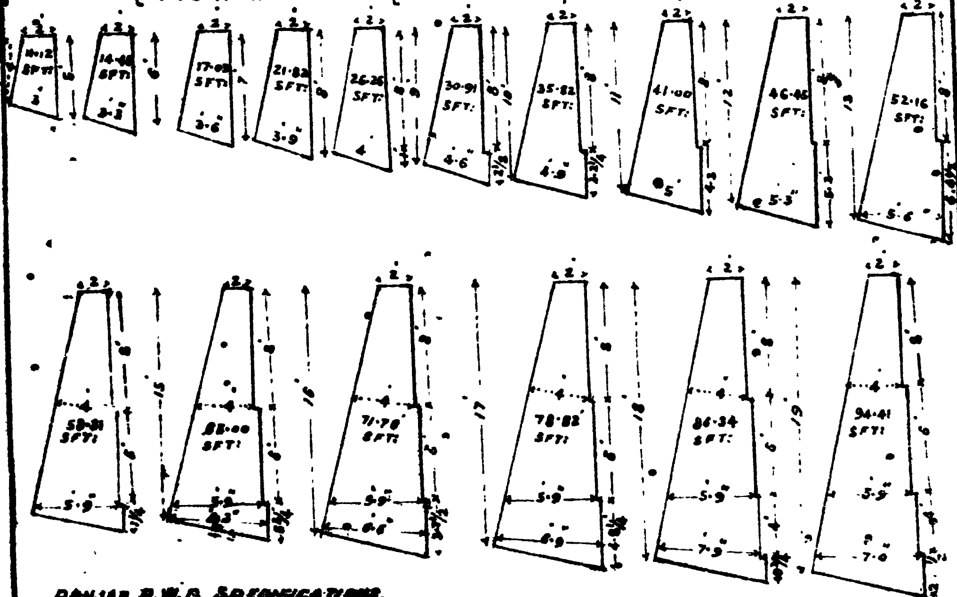
DRY STONE MASONRY REVETMENT WALLS ON HILL ROADS

SCALE = 16' = 1"

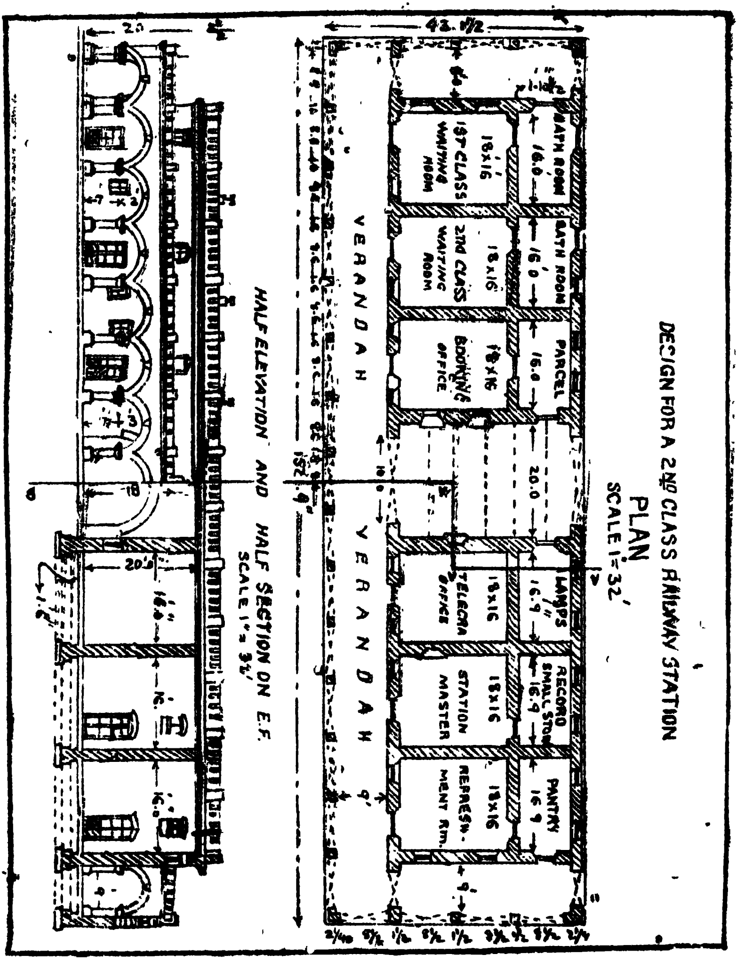
TOP WIDTH = 2 FEET
STEPS AT BACK 3"

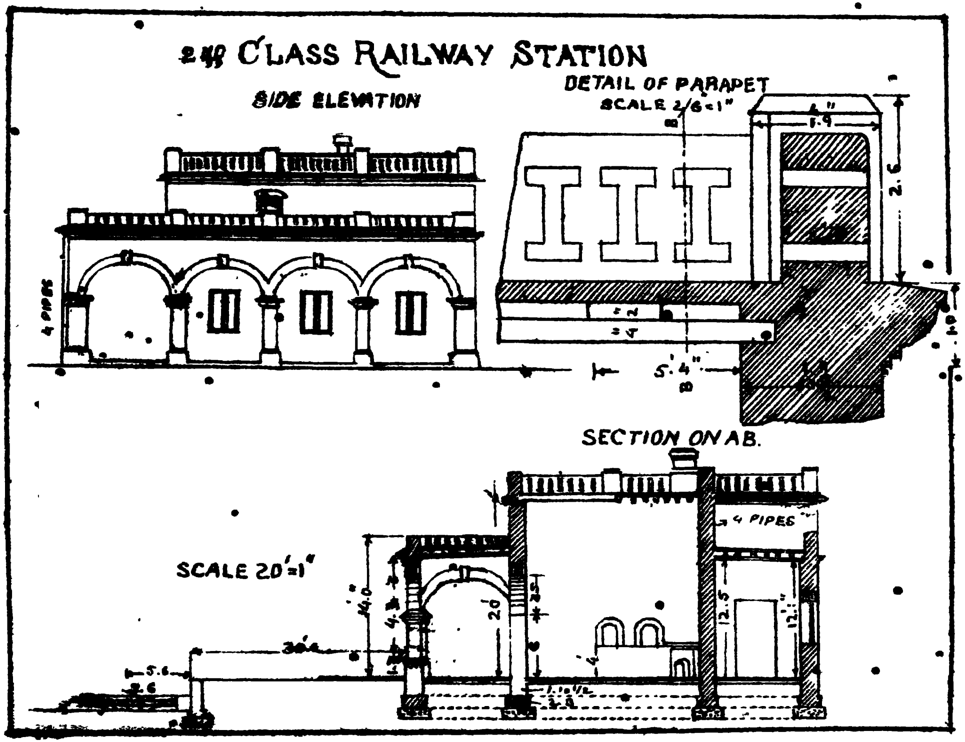
FACE BATTER 4 TO 1
FOUNDATION AT RIGHT ANGLE TO FACE.

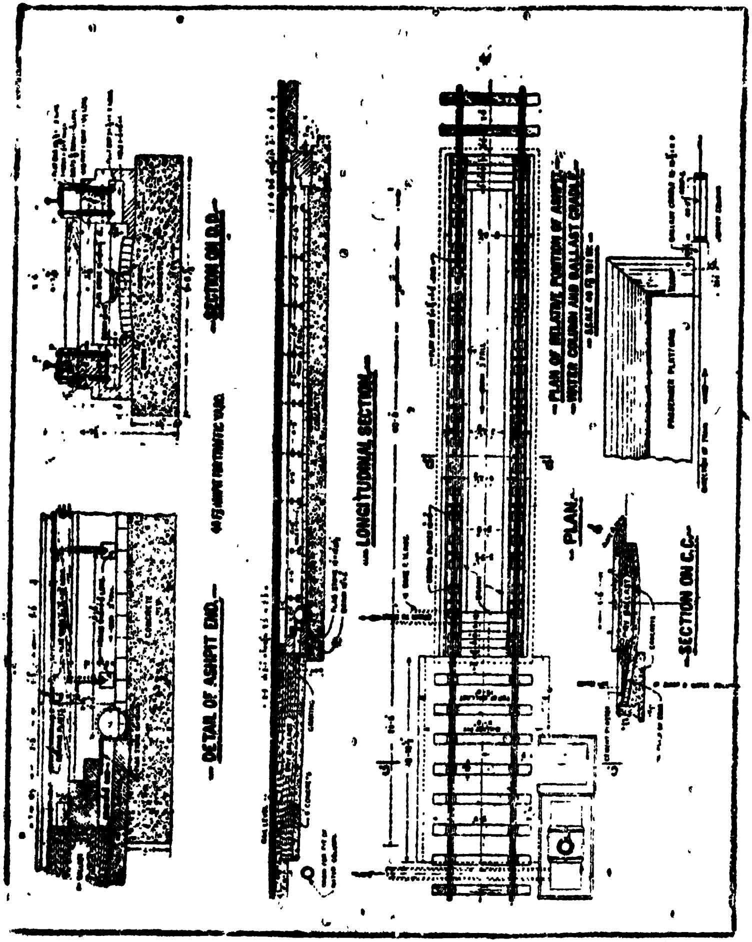
BACK VERTICAL

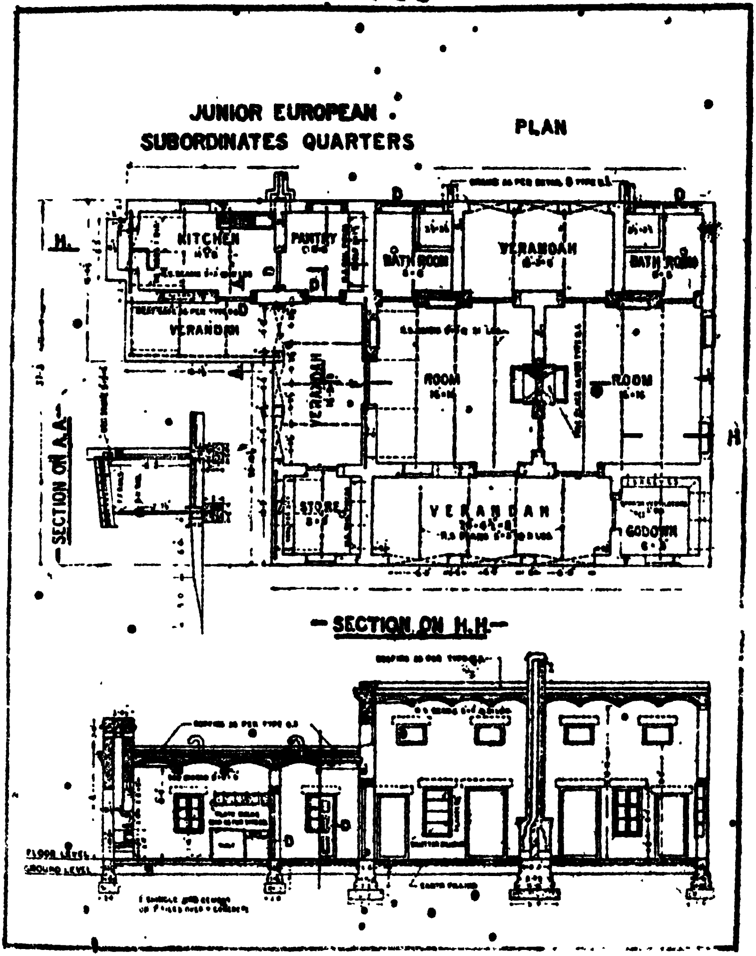


PUNJAB P.W.D. SPECIFICATIONS.


DESIGN FOR A 2ND CLASS RAILWAY STATION
PLAN
SCALE 1"=32'
BATH ROOM
1ST CLASS WAITING ROOM
BATH ROOM
2ND CLASS WAITING ROOM
PARCEL
BOOKING OFFICE
LAMPS
TELEGRA OFFICE
RECORD SMALL STO
STATION MASTER
PANTRY
REFRESH-MENT RM.
VERANDAH
VERANDAH
HALF ELEVATION AND HALF SECTION ON E.F.


2nd CLASS RAILWAY STATION
SIDE ELEVATION
4 PIPES
DETAIL OF PARAPET
SCALE 2/6=1"
2.6
1.9
5.4"
SECTION ON AB.
4 PIPES
SCALE 20'=1"
14.0
20
12.5
30'4
5.6

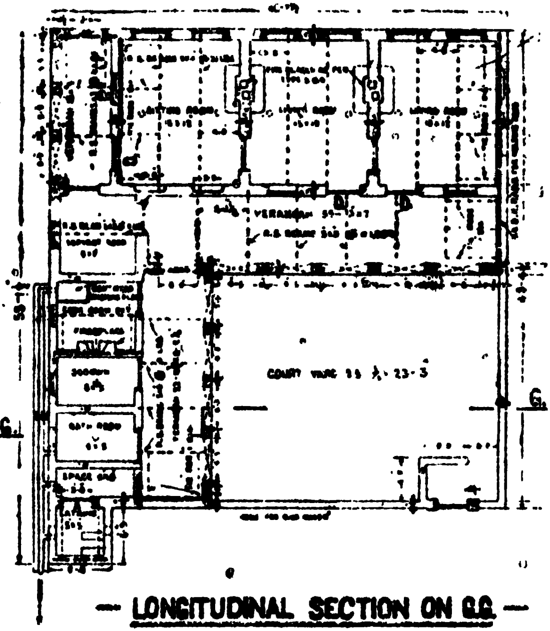

SECTION ON D.D.
DETAIL OF ASHPIT END
LONGITUDINAL SECTION
PLAN OF RELATIVE POSITION OF ASHPIT WATER COLUMN AND BALLAST CRADLE
PLAN
SECTION ON C.C.
PASSENGER PLATFORM



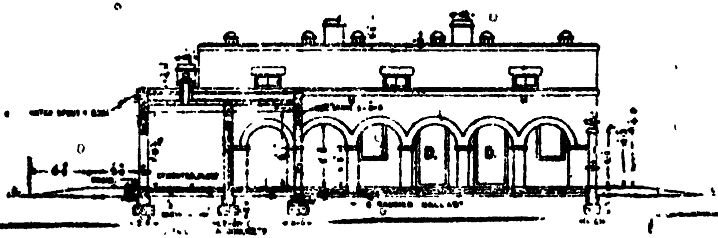
JUNIOR EUROPEAN
SUBORDINATES QUARTERS
PLAN
KITCHEN
PANTRY
BATH ROOM
VERANDAH
BATH ROOM
VERANDAH
VERANDAH
ROOM
ROOM
STORE
VERANDAH
GODOWN
SECTION ON A.A.
SECTION ON H.H.
FLOOR LEVEL
GROUND LEVEL

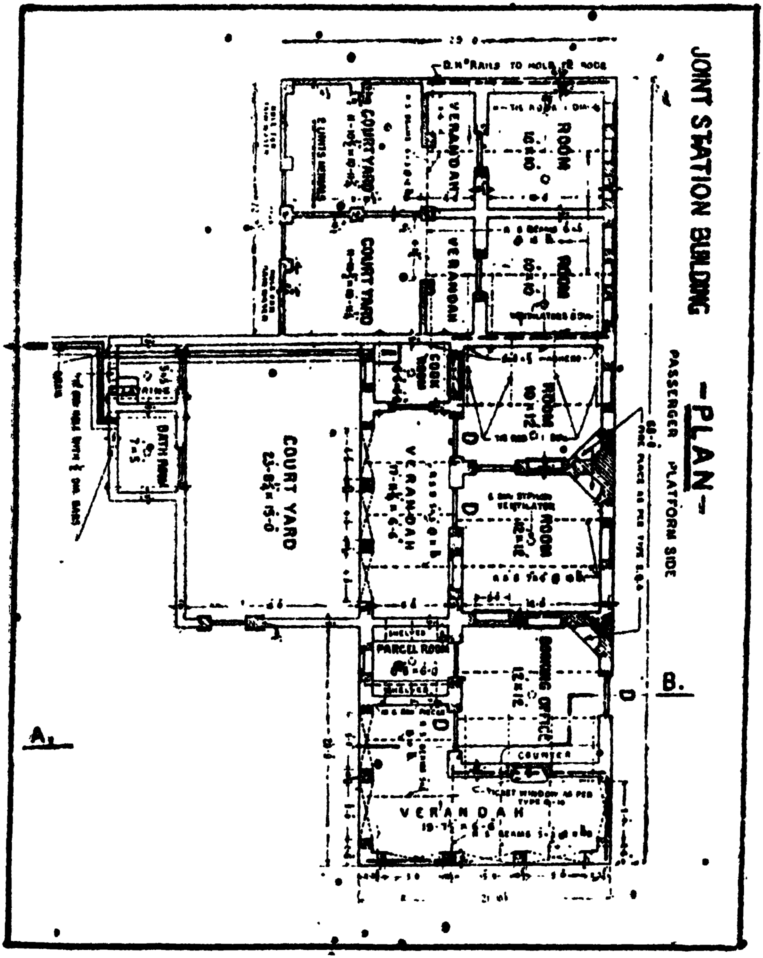
SENIOR INDIAN SUBORDINATES QUARTERS.

PLAN



— LONGITUDINAL SECTION ON G.G. —

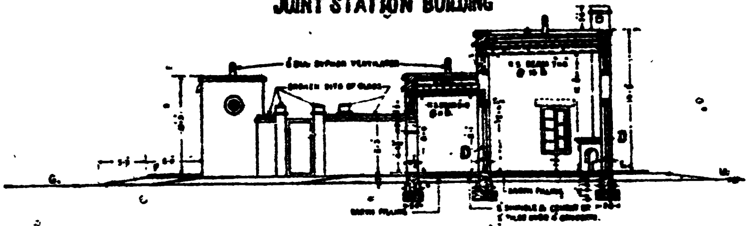




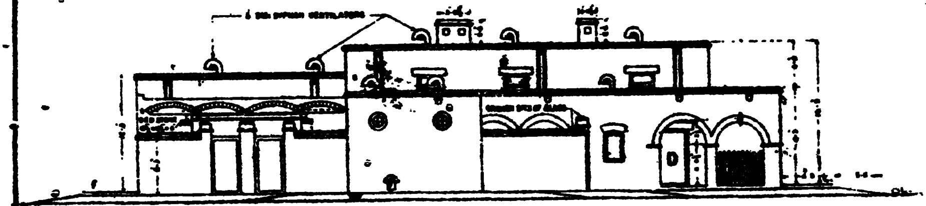
JOINT STATION BUILDING
-PLAN-
PASSENGER PLATFORM SIDE
ROOM
VERANDAH
COURT YARD
COURT YARD
23-8½ x 15-0
VERANDAH
COOK ROOM
BATH ROOM
PARCEL ROOM
BOOKING OFFICE
COUNTER
VERANDAH
A.
B.
D

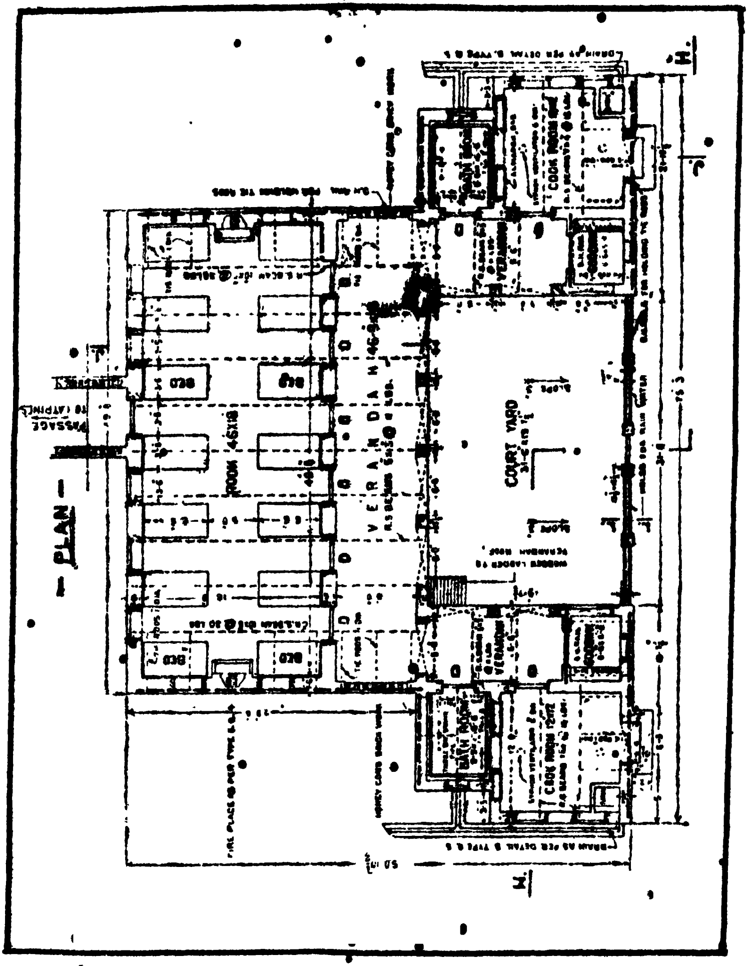
—SECTION ON A.B—

JOINT STATION BUILDING

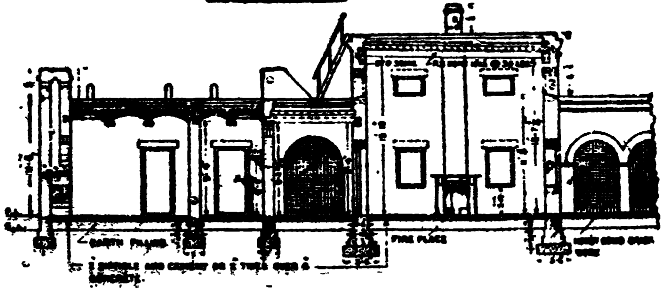


—BACK ELEVATION—

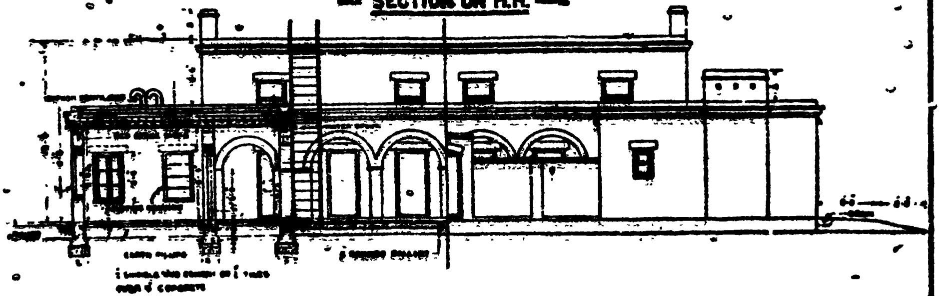


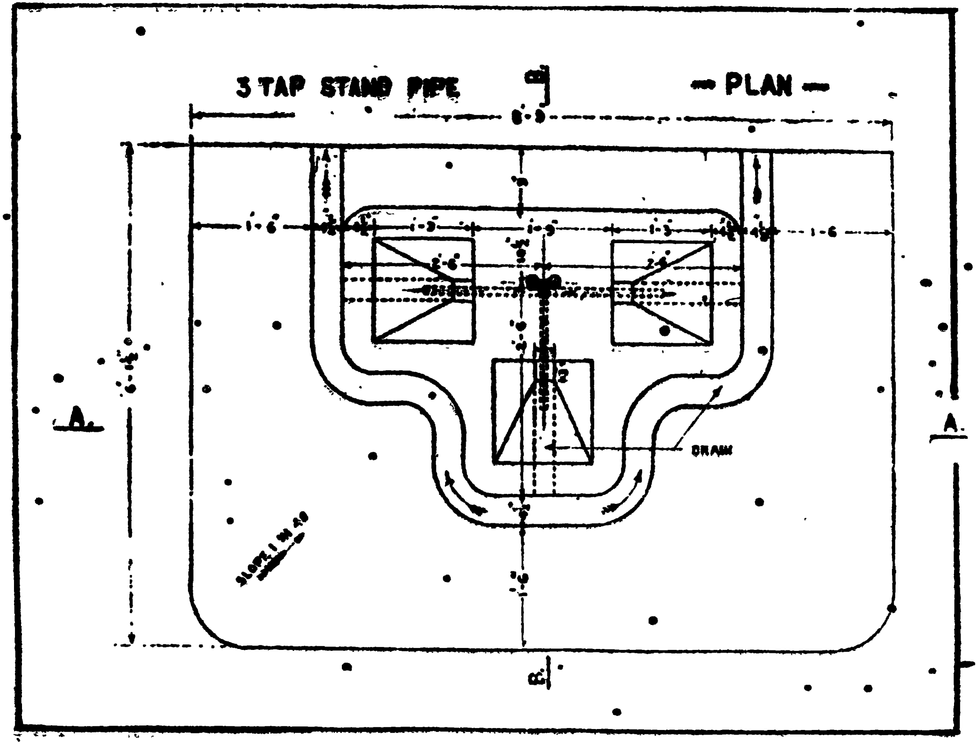

PLAN
ROOM 46'x18'
V E R A N D A H
COURT YARD
BED
VERANDAH
COOK ROOM
BATH ROOM
PASSAGE

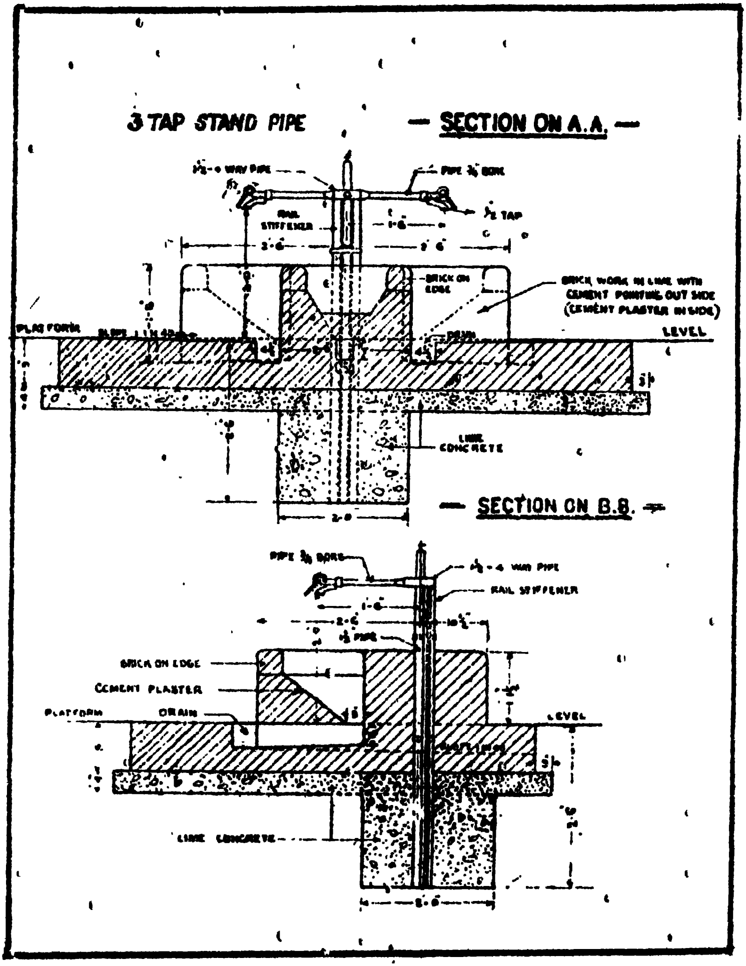
SECTION ON J.J.

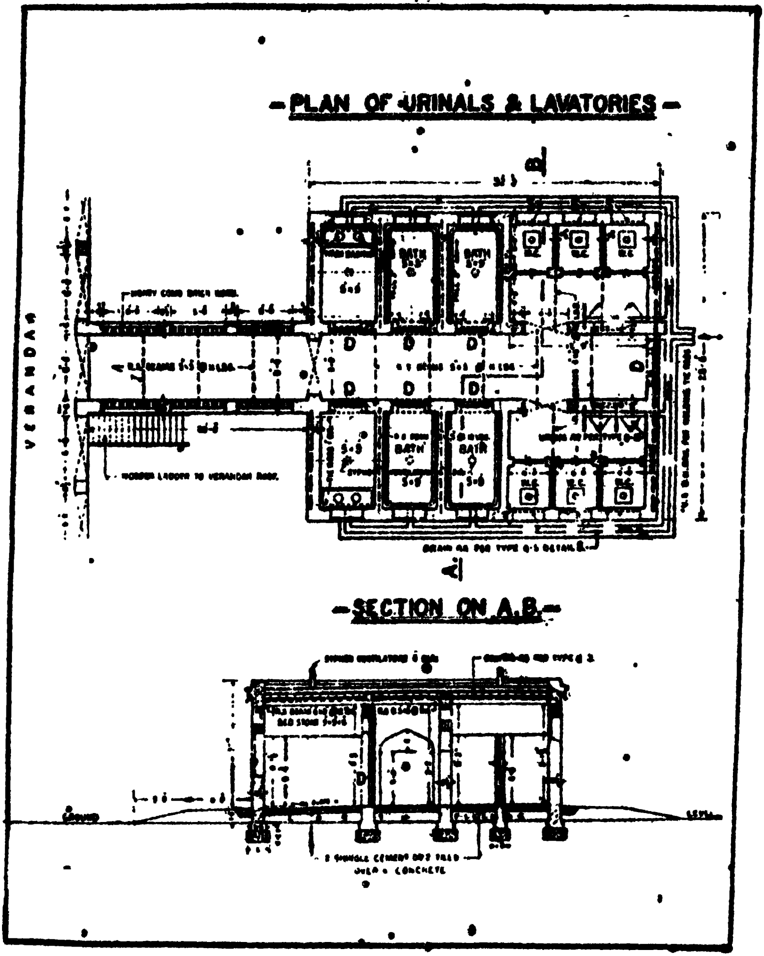


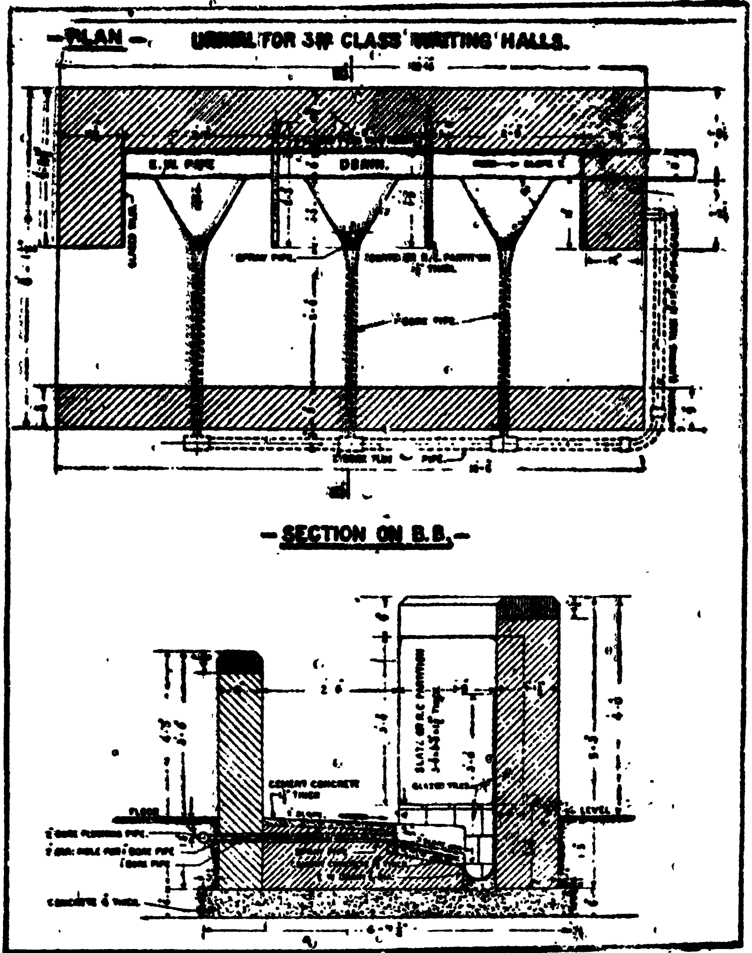
SECTION ON H.H.

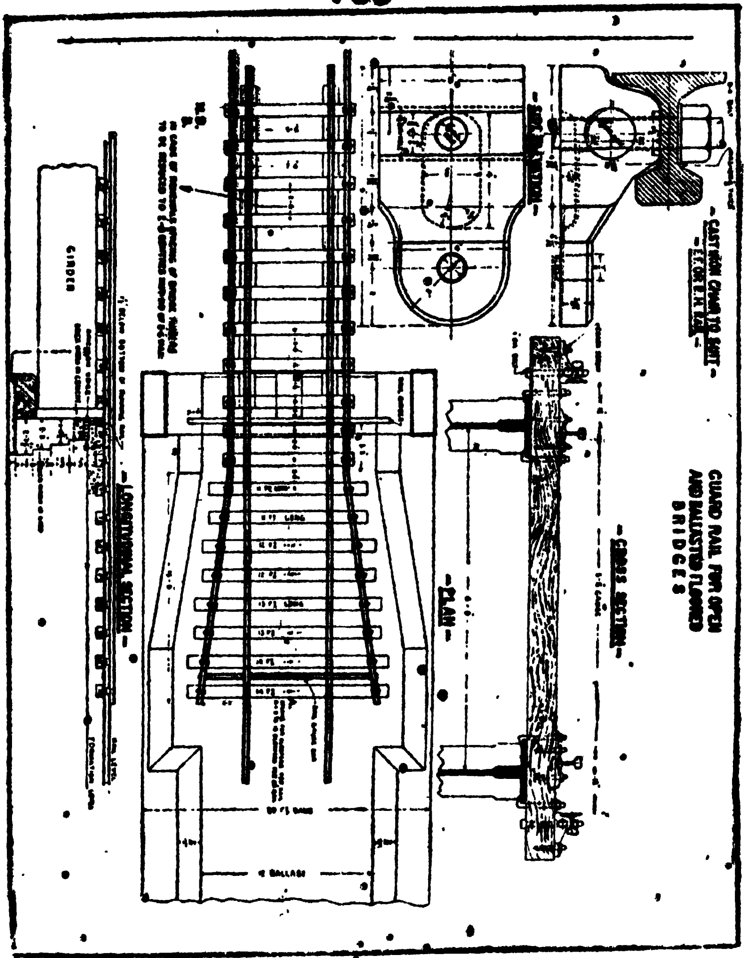



3 TAP STAND PIPE
— PLAN —
6'-9"
1'-6"
1'-3"
2'-6"
DRAIN
SLOPE 1 IN 40
A.
A.

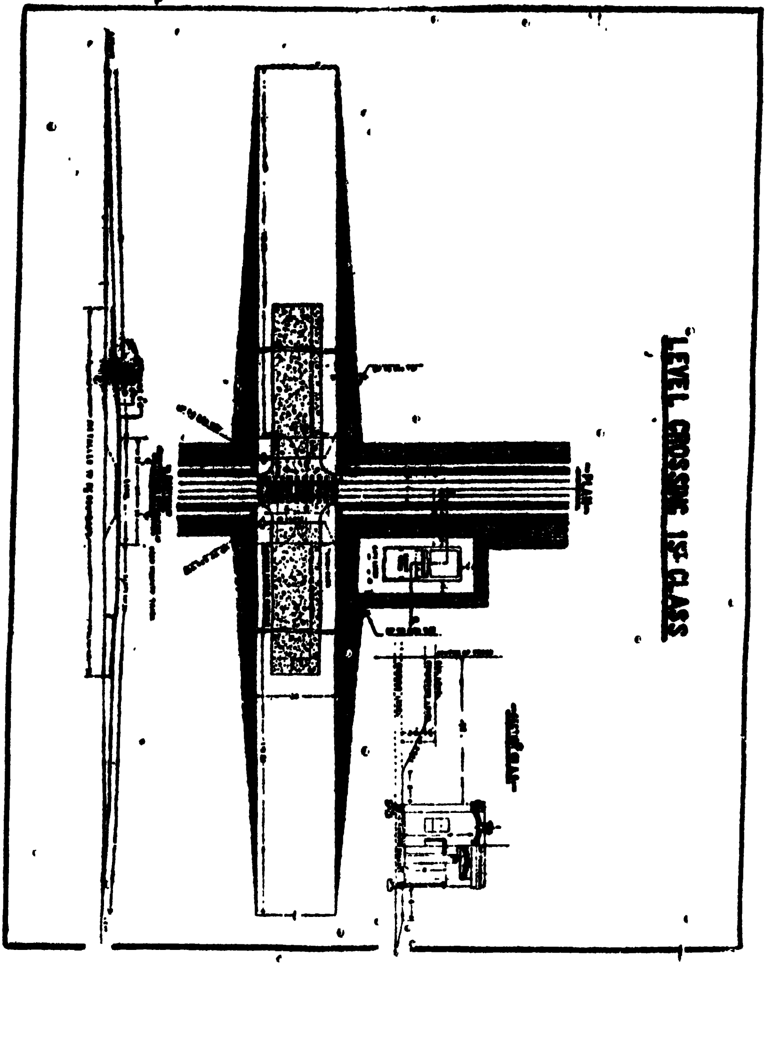

3 TAP STAND PIPE
— SECTION ON A.A. —
PIPE ¾" BORE
½" TAP
RAIL STIFFENER
BRICK ON EDGE
BRICK WORK IN LIME WITH CEMENT POINTING OUT SIDE (CEMENT PLASTER INSIDE)
PLATFORM
LEVEL
DRAIN
LIME CONCRETE
— SECTION ON B.B. —
PIPE ¾" BORE
RAIL STIFFENER
BRICK ON EDGE
CEMENT PLASTER
PLATFORM
DRAIN
LEVEL
LIME CONCRETE


PLAN OF URINALS & LAVATORIES
VERANDAH
BATH
W.C.
D
SECTION ON A.B.
GROUND
LEVEL

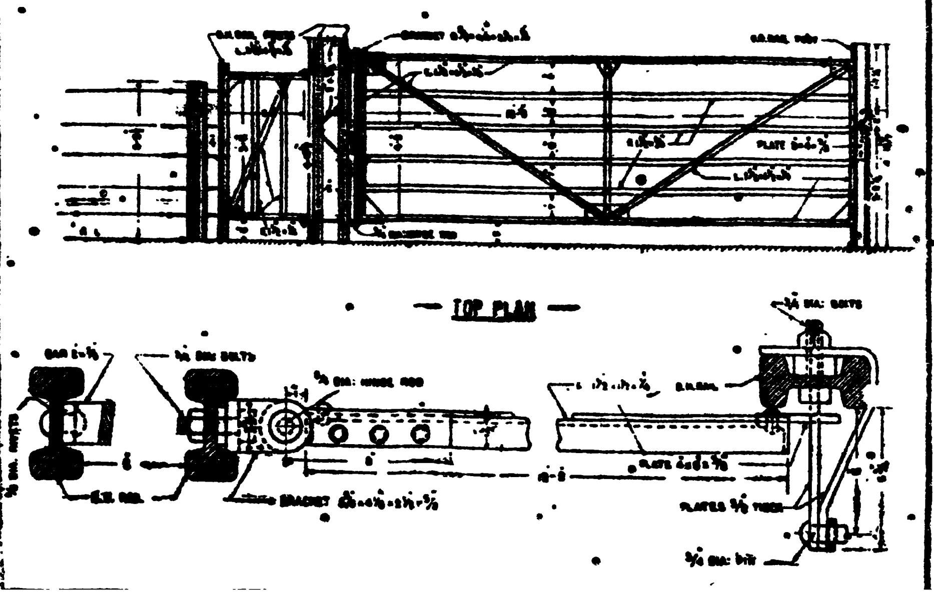

PLAN
URINAL FOR 3RD CLASS WAITING HALLS.
DRAIN.
SECTION ON B.B.
CEMENT CONCRETE
FLOOR
LEVEL



GUARD RAIL FOR OPEN AND BALLASTED FLOORED BRIDGES
CAST IRON CHAIR TO SUIT
CROSS SECTION
PLAN
LONGITUDINAL SECTION
GIRDER


LEVEL CROSSING 1ST CLASS

12 FT GATE FOR 2ND CLASS LEVEL XING



WATER WORKS

FLOW OF WATER THROUGH PIPES

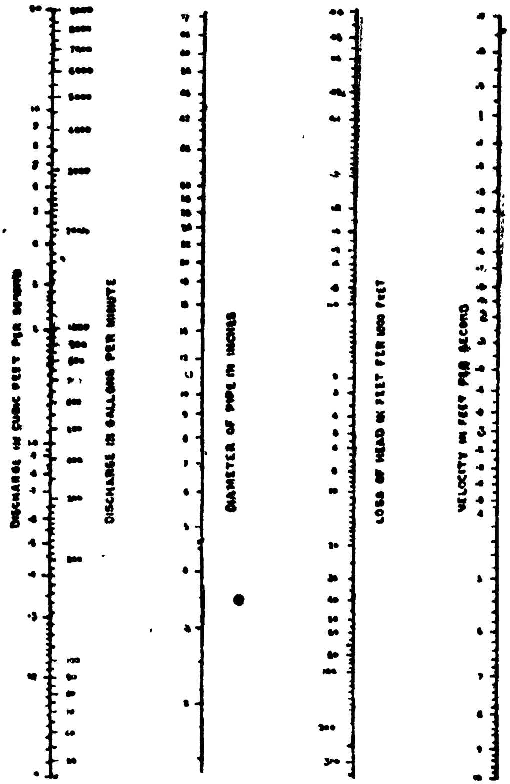
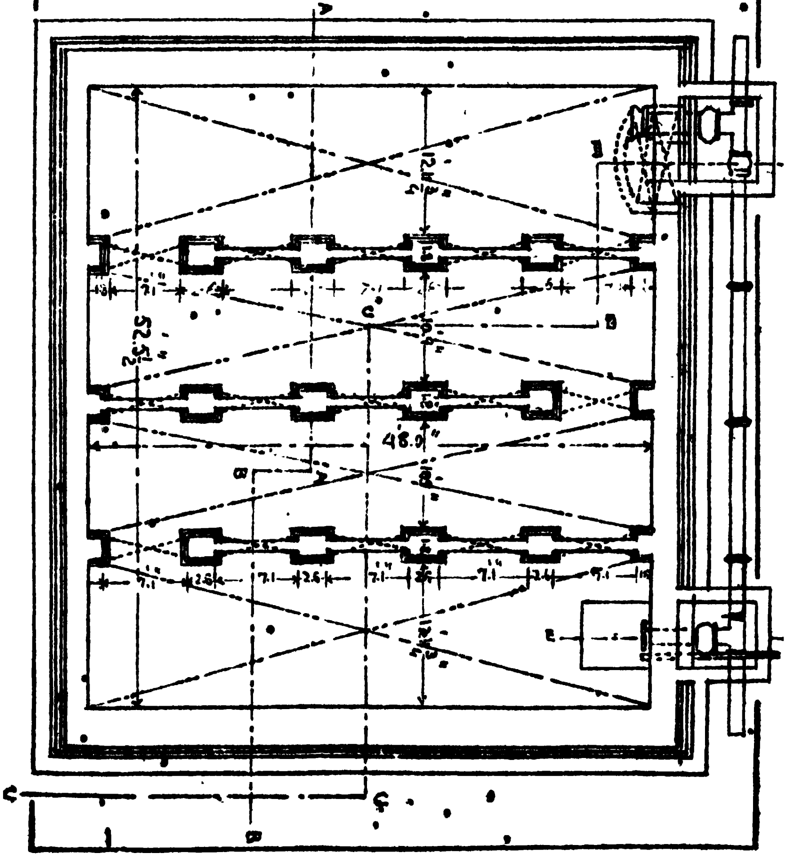


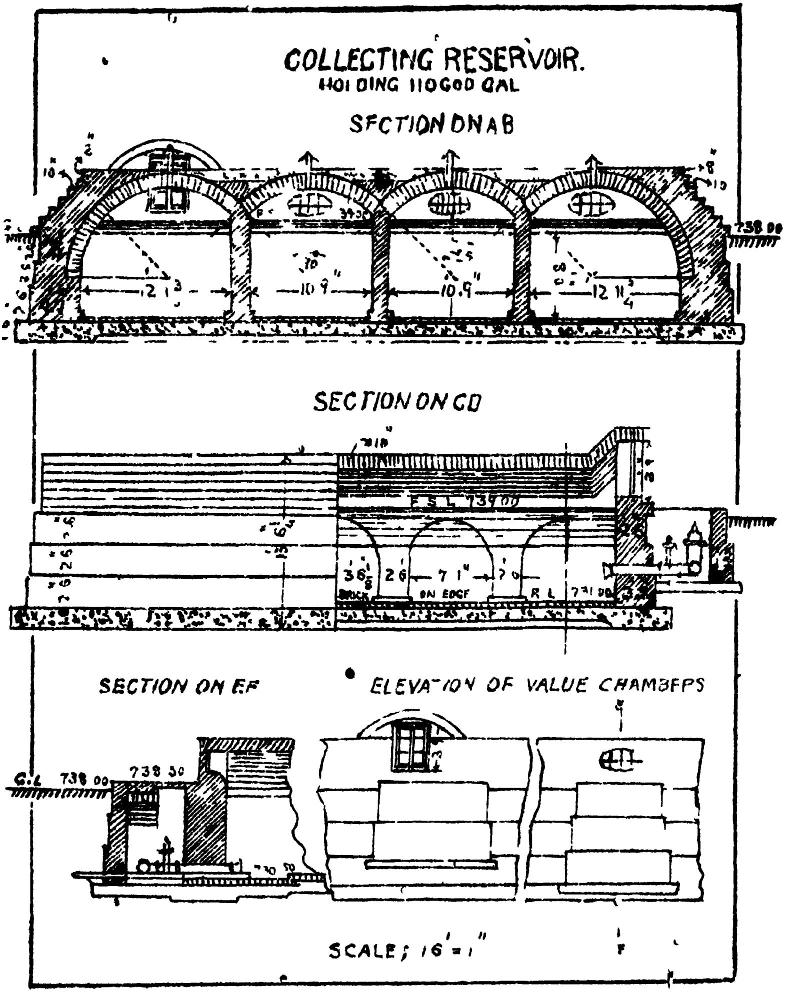
DIAGRAM FOR CALCULATING CAST-IRON PIPE

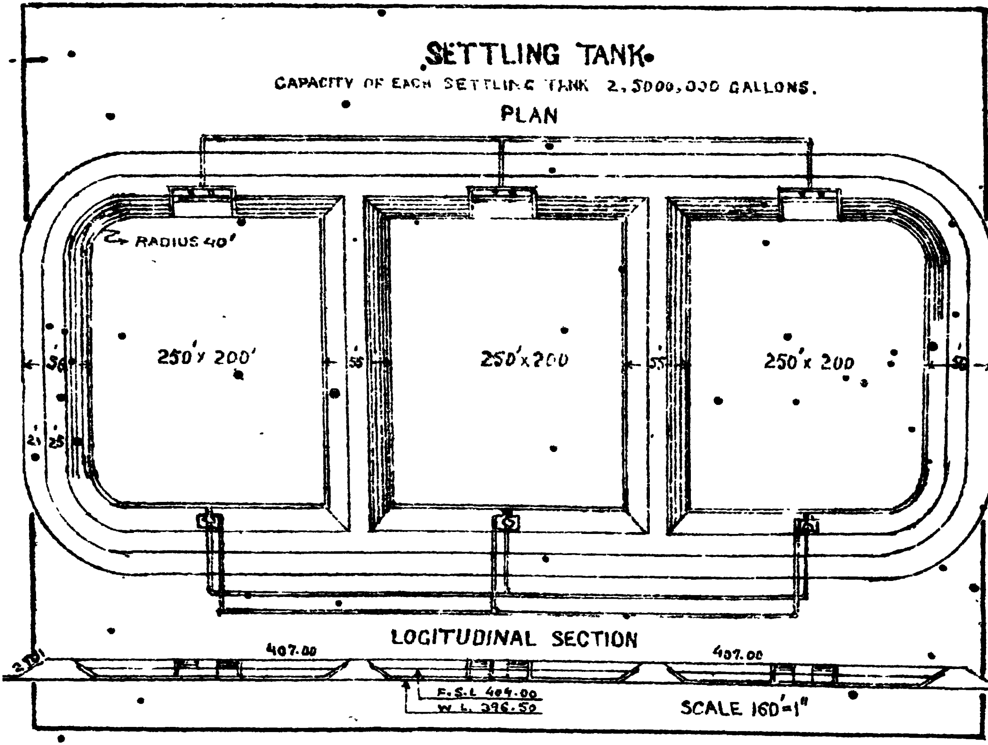
(Hazen-Williams $C_1 = 120$)

WATER WORKS.

PLAN OF A COLLECTING RESERVOIR HOLDING 110600 GALNS



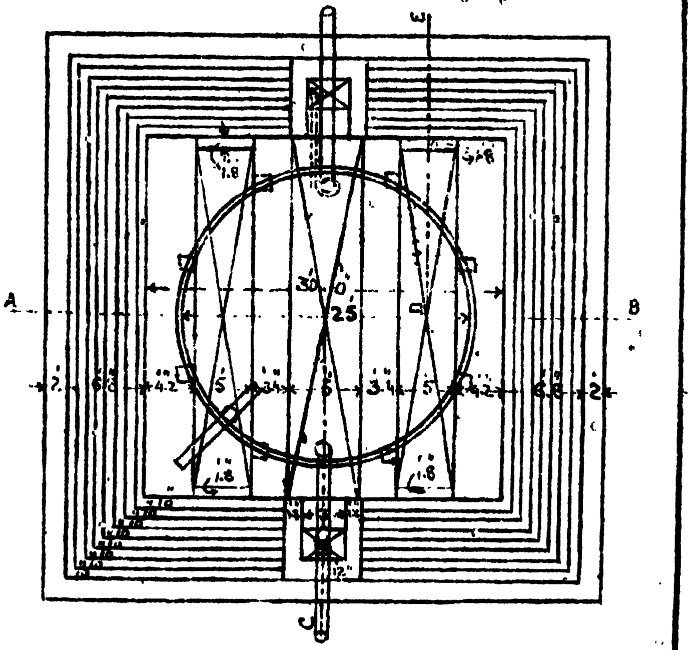

COLLECTING RESERVOIR.
HOLDING 110600 GAL
SECTION ON AB
SECTION ON CD
F S L 739 00
BRICK ON EDGE
R L 731 00
SECTION ON EF
ELEVATION OF VALUE CHAMBERS
G.L 738 00
738 50
SCALE; 16'=1"

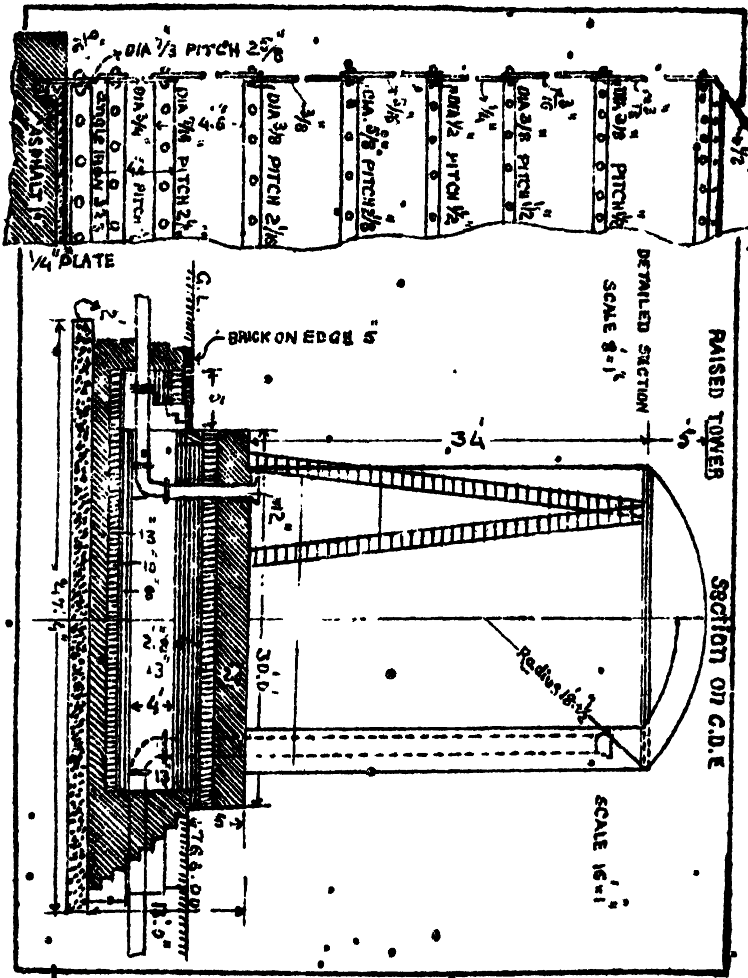

SETTLING TANK.
CAPACITY OF EACH SETTLING TANK 2,5000,000 GALLONS.
PLAN
RADIUS 40'
250' x 200'
250' x 200
250' x 200
56
55
55
50
21
25
LOGITUDINAL SECTION
407.00
407.00
F.S.L 404.00
W.L. 396.50
SCALE 160'=1"

RAISED TOWER

Scale, 16' = 1"

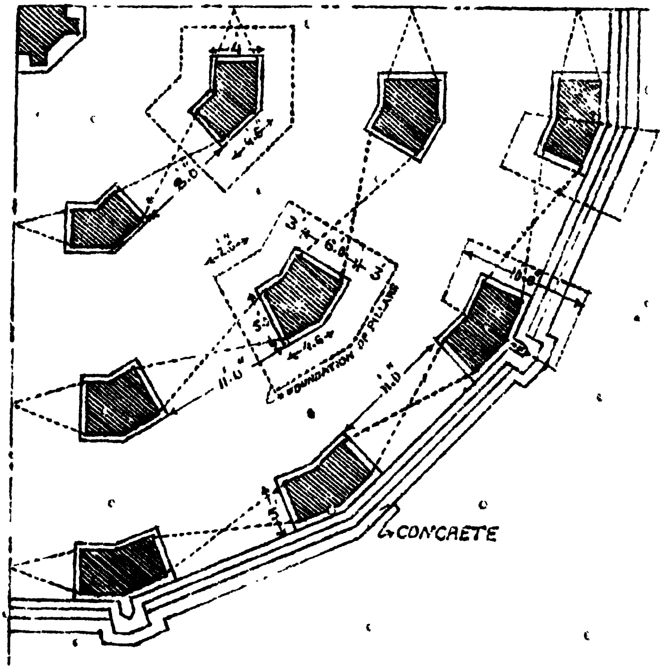
GROUND PLAN

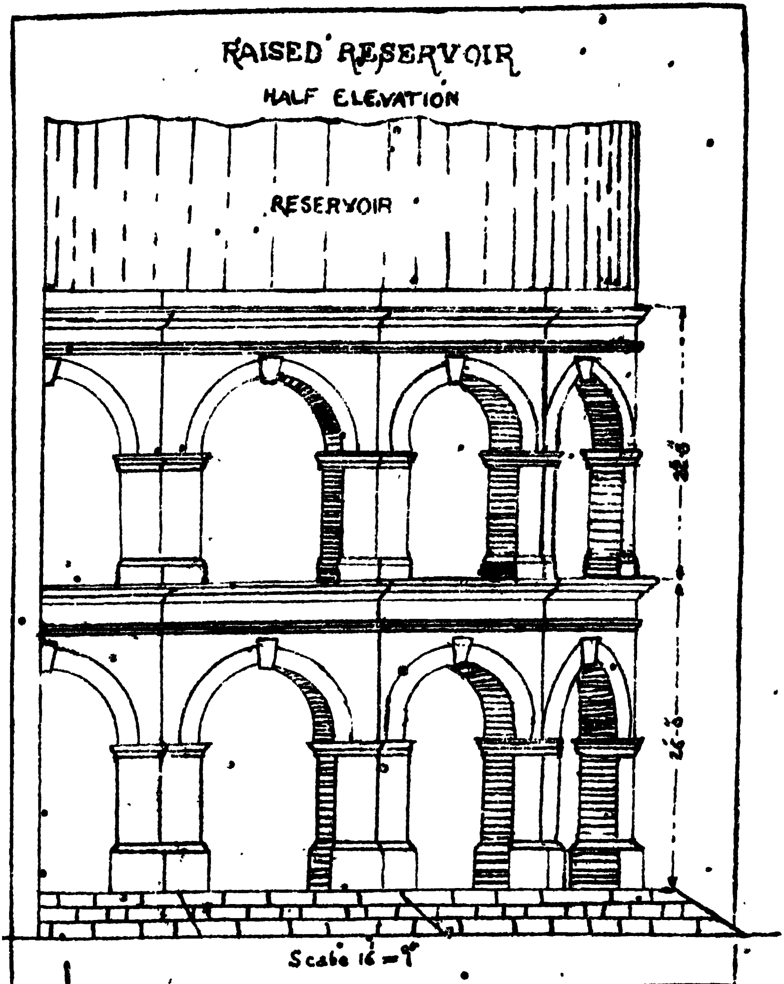


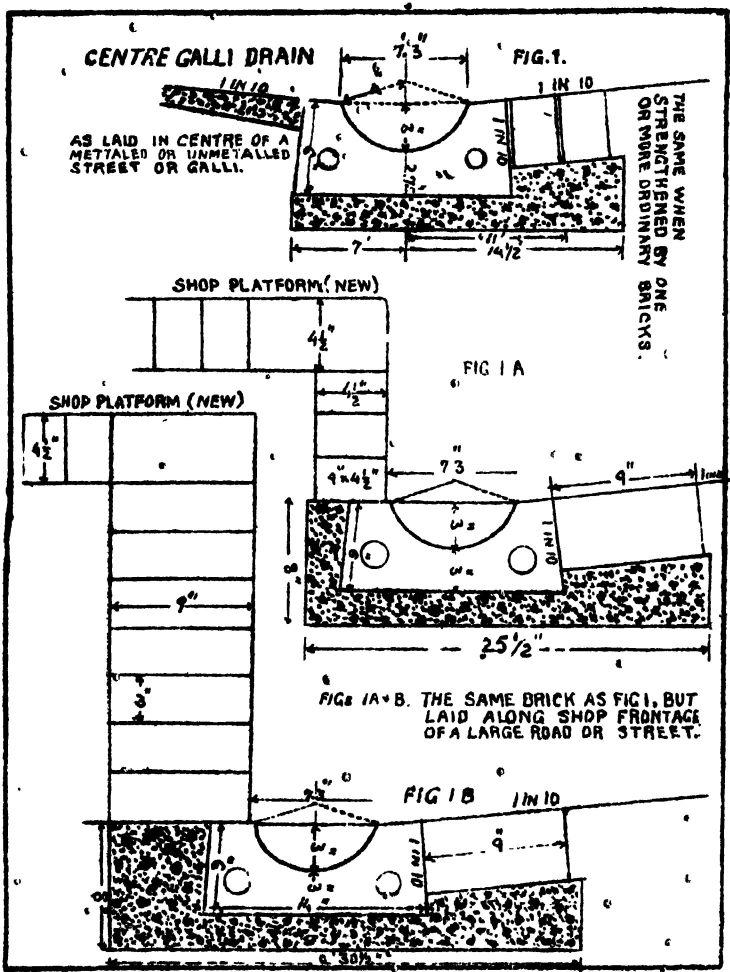

RAISED TOWER
SECTION ON C.D.E
SCALE 16'=1"
DETAILED SECTION
BRICK ON EDGE 5"
1/4" PLATE
ASPHALT
G.L.
34'
30.0'

QUARTER PLAN OF RAISED RESERVOIR.

SCALE 16′=1″




RAISED RESERVOIR
HALF ELEVATION
RESERVOIR



FIGs IA + B. THE SAME BRICK AS FIG I, BUT LAID ALONG SHOP FRONTAGE OF A LARGE ROAD OR STREET.

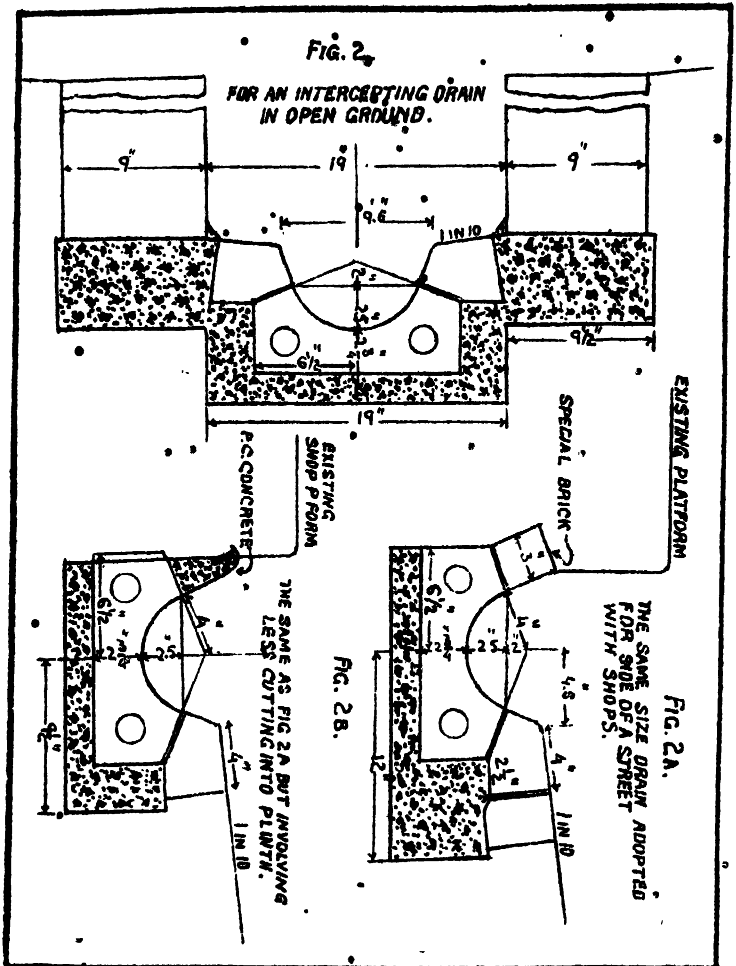
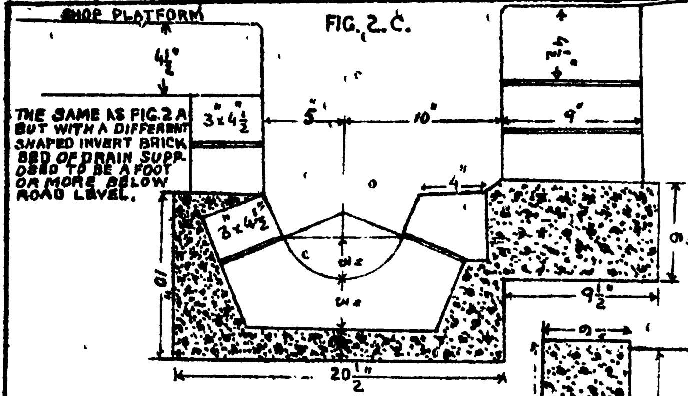

FOR AN INTERCEPTING DRAIN
IN OPEN GROUND.
9"
19"
9"
9.6"
1 IN 10
9½"
6½"
19"
EXISTING PLATFORM
SPECIAL BRICK
EXISTING
SHOP P.FORM
P.C. CONCRETE
THE SAME SIZE DRAIN ADOPTED
FOR SIDE OF A STREET
WITH SHOPS.
FIG. 2A.
FIG. 2B.
THE SAME AS FIG 2A BUT INVOLVING
LESS CUTTING INTO PLINTH.
1 IN 10
4.8"
4"
2½"
12"

FIG. 2.

FIG. 2. C.



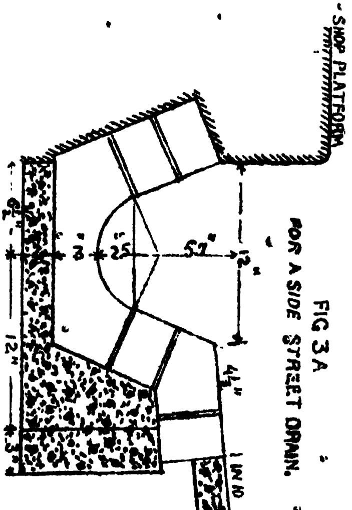


FIG 3A
FOR A SIDE STREET DRAIN.

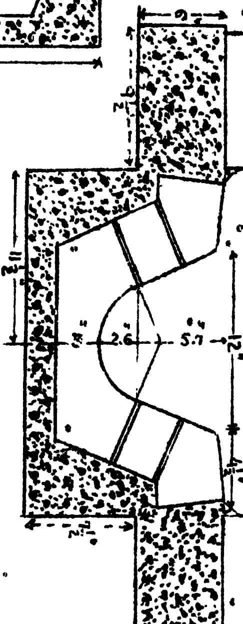
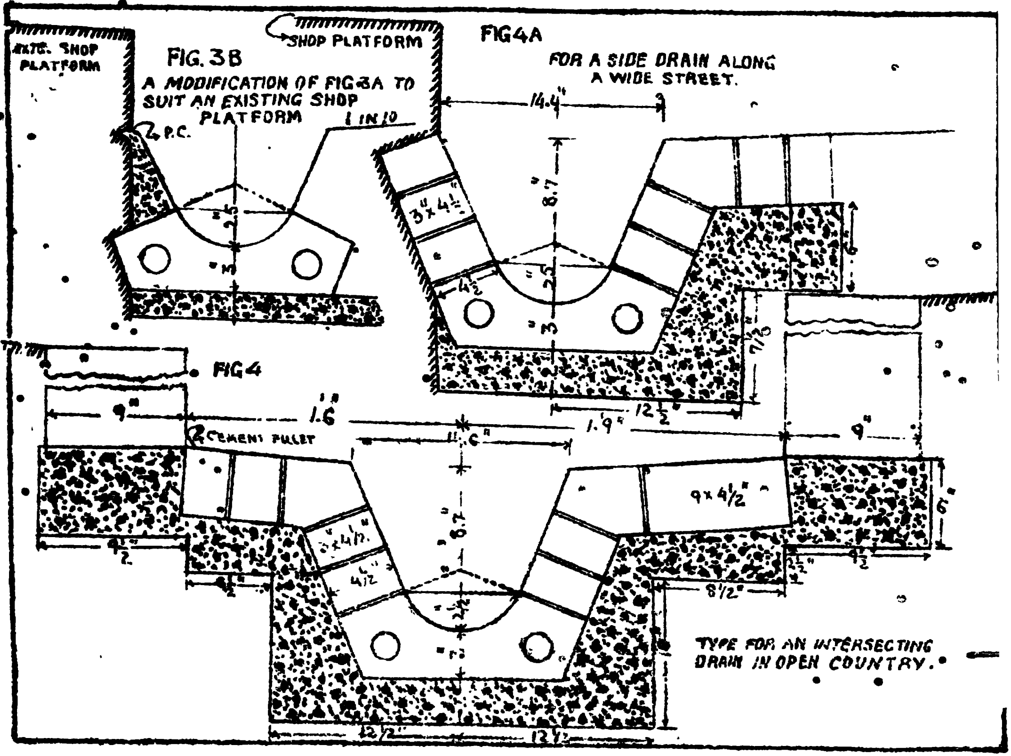


FIG. 3.
FOR AN INTERCEPTING DRAIN IN OPEN COUNTRY.


EXTG. SHOP PLATFORM
FIG. 3B
A MODIFICATION OF FIG 3A TO SUIT AN EXISTING SHOP PLATFORM
SHOP PLATFORM
1 IN 10
P.C.
FIG 4A
FOR A SIDE DRAIN ALONG A WIDE STREET.
14.4"
8.7"
3"x4½"
4½"
12½"
7½"
1.9"
9"
FIG 4
CEMENT FILLET
1.6"
9"
9x4½"
6"
8½"
12½"
TYPE FOR AN INTERSECTING DRAIN IN OPEN COUNTRY.

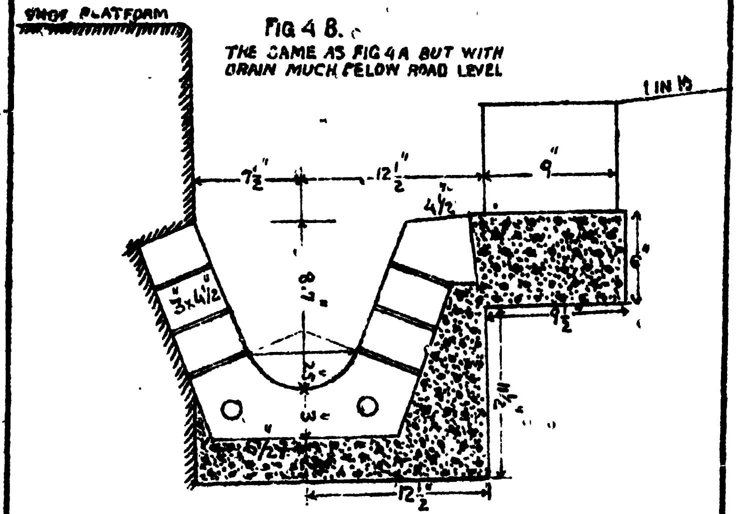


FIG 4 B.
THE SAME AS FIG 4A BUT WITH DRAIN MUCH BELOW ROAD LEVEL

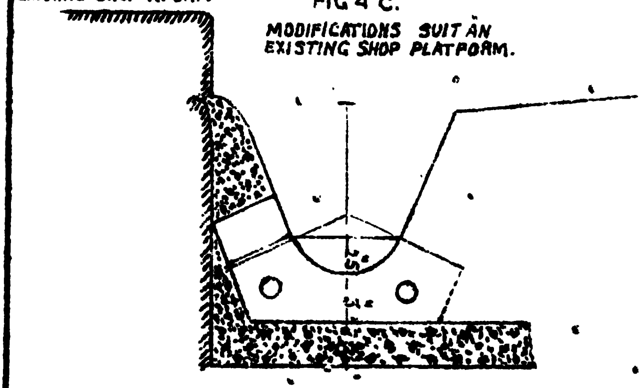


FIG 4 C.
MODIFICATIONS SUIT AN EXISTING SHOP PLATFORM.

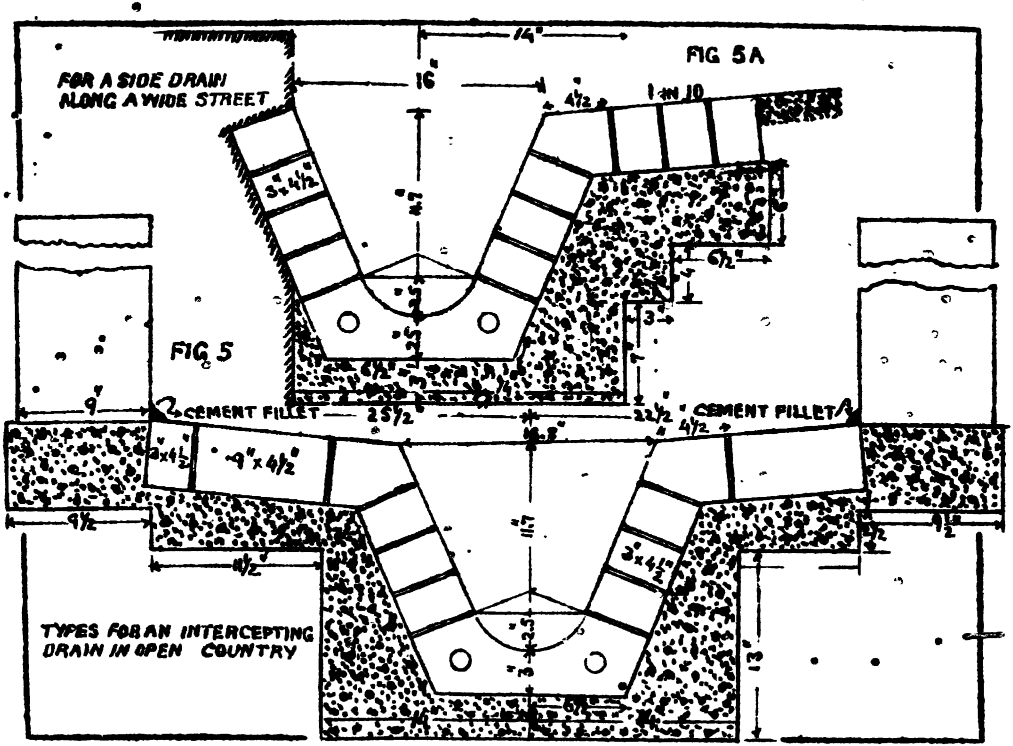

FIG 5A
FOR A SIDE DRAIN ALONG A WIDE STREET
14"
16"
4½"
1 in 10
3"×4½"
6½"
3"
FIG 5
9"
CEMENT FILLET
25½"
22½"
CEMENT FILLET
4½"
9"×4½"
3"×4½"
9½"
11½"
13"
TYPES FOR AN INTERCEPTING DRAIN IN OPEN COUNTRY

FIG. 6.

THIS SIZE WOULD ONLY BE USED FOR A LARGE INTERCEPTING DRAIN, SIDE WALLS ABOVE CONCRETE NOT SHOWN.

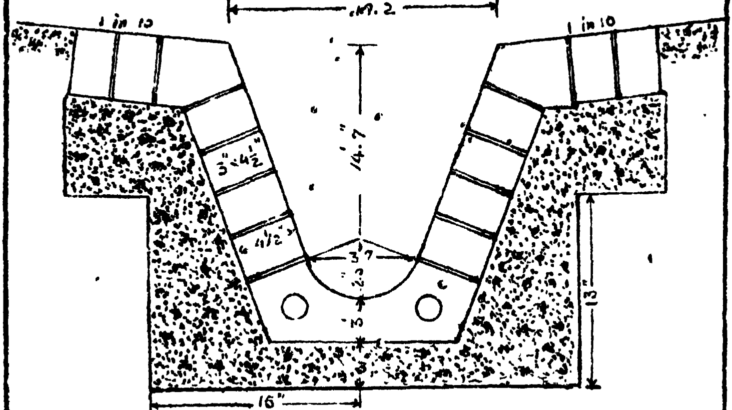
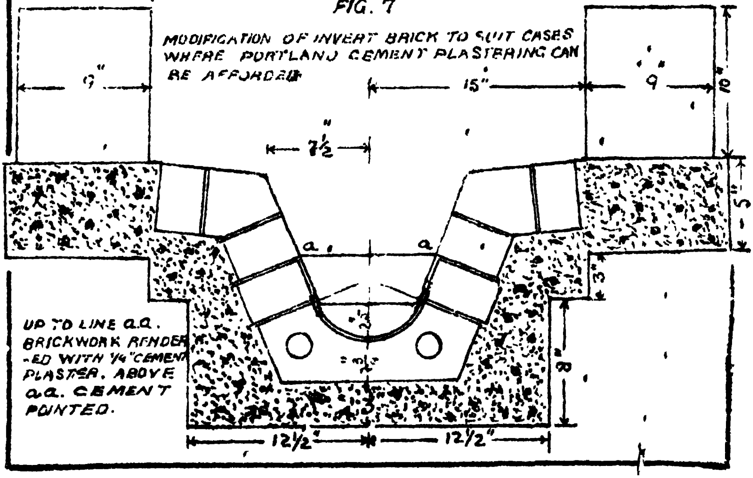
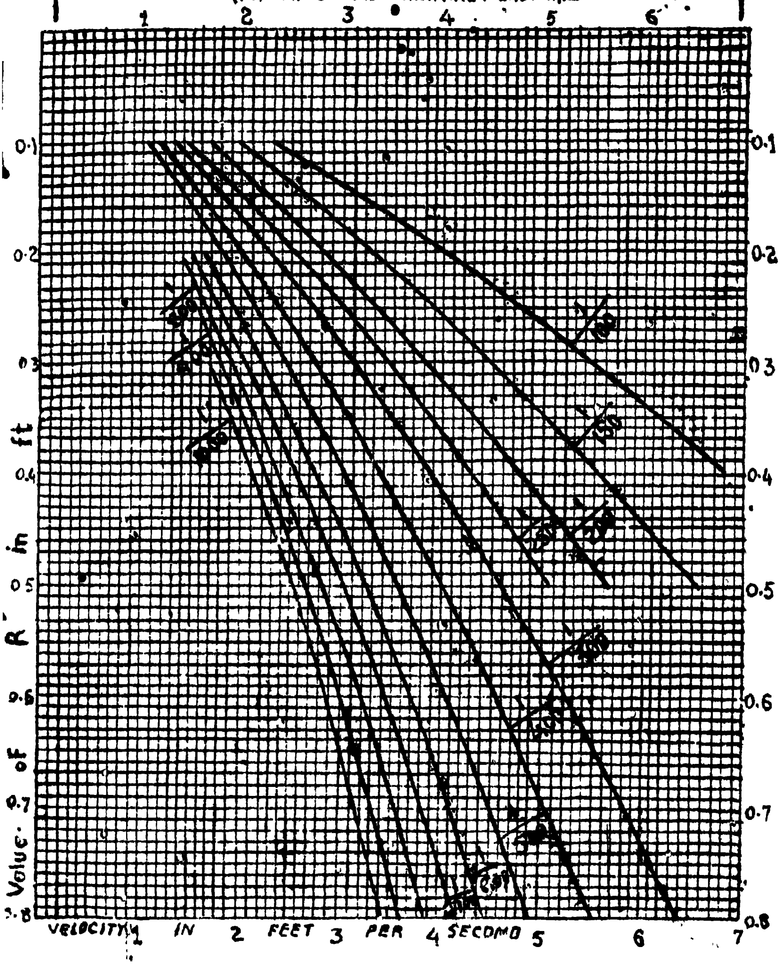


FIG. 7

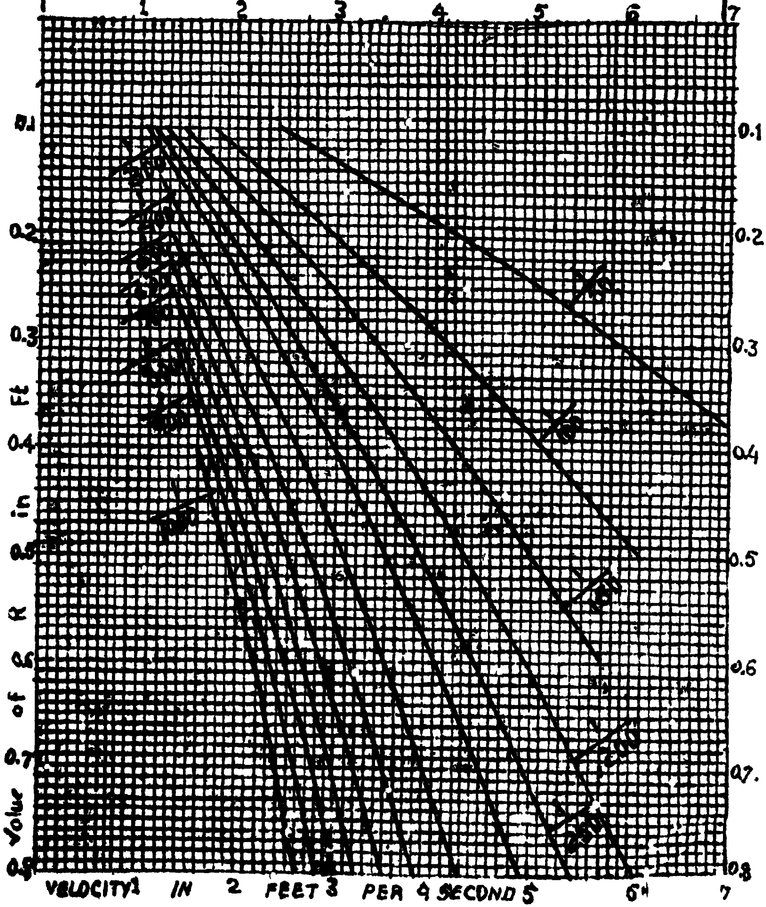
MODIFICATION OF INVERT BRICK TO SUIT CASES WHERE PORTLAND CEMENT PLASTERING CAN BE AFFORDED



VELOCITY CURVES FOR KUTTUR'S FORMULA WITH N = ·012
(A) FOR DRAINS WHICH ARE PLASTERED



VELOCITY CURVES FOR KUTTERS FORMULA WITH N·015
(B) FOR BRICKWORK IN POINTING



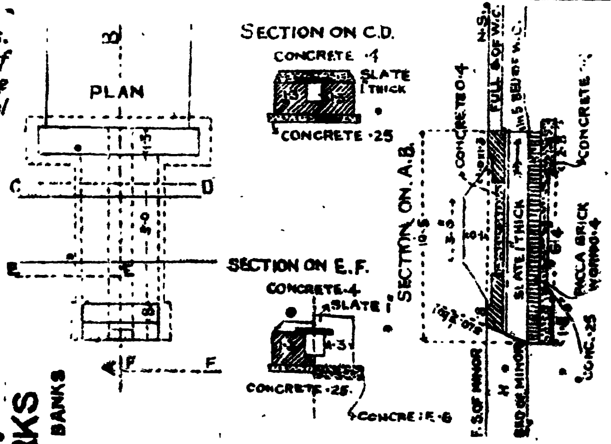
Notes.—(1) The length of barrel to be 7′ + 1½ times the f. s. depth. (2) The parapets of up and down wells to be exactly at designed f. s. level of the distributary.

SIZE	DIMENSIONS OF BARREL					THICKNESS OF ABUTMENT	WIDTH OF SLATE
	WIDTH IN FEET	or IN.	HEIGHT IN FEET	or IN.	AREA IN SQ. FT.		
½ π	0·25	3	·25	3	·0625	•	
1 π	0·4	Dia. is the			·125		
1½ π	·375	4½	0·5	6	·1875	·8	
2 π	·5	6	0·5	5	·25	·8	
2½ π	·625	7½	0·5	6	·325	·8	
3 π	·5	6	·75	9	·375	·8	
3½ π	·583	7	·75	9	·4375	·8	
4 π	·5	6	1·0	12	·5	·8	
5 π	·625	7½	1·0	12	·625	·8	
6 π	·75	9	1·0	12	·75	1·3	
7 π	·875	10½	1·0	12	·875	1·3	1·25
8 π	1·0	12	1·0	12	1·0	1·3	1·5
9 π	1·125	13½	1·0	12	1·125	1·3	1·5
10 π	1·25	15	1·0	12	1·25	1·3	1·75

CANAL WORKS

OUTLET HEAD IN MINOR BANKS

Scale = 1/100



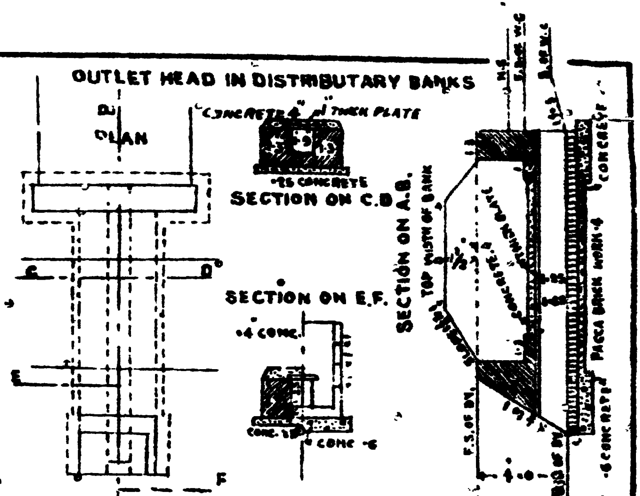
(3) The floor of the Outlet to be at designed bed level of the distributary. (4) When the width of the outlet is 9″ or less it will be roofed with bricks instead of slates. (5) The standard "π" is a pipe of 0′·4 dia. A pipe of 0′·5 dia = 1½ π.

OUTLET HEAD IN DISTRIBUTARY BANKS

SIZE	Dimension of Barrels: Width in feet	Dimension of Barrels: Height in feet	Area	Thickness of Abutments	Width of Slate
1	Pipe diameter				
2	0·5	0·5	0·25	0·8	
3	0·5	0·75	0·37	0·8	
4	0·5	1·0	0·5	0·8	
5	0·56	1·0	0·56	0·8	1·25
6	0·75	1·0	0·75	1·3	1·25
7	0·75	1·25	0·93	1·3	1·25
8	1·0	1·0	1·00	1·3	1·5
9	0·9	1·25	1·13	1·3	1·5
10	1·0	1·25	1·25	1·3	1·5
11	1·1	1·25	1·38	1·3	1·5
12	1·25	1·25	1·56	1·3	1·75
13	1·3	1·25	1·62	1·3	1·75
14	1·4	1·25	1·75	1·3	2·0
15	1·5	1·25	1·88	1·3	2·0
16	1·6	1·25	2·0	1·3	2·25
17	1·7	1·25	2·13	1·3	2·25
18	1·5	1·5	2·26	1·3	2·25

Where the width of outlet is 0·5 or less it will be roofed with brick instead of slate.

Scale = 1/100



Note — Formula used is $D = C A \sqrt{2gh}$, where $\sqrt{2g} = 8$
D = discharge per second, A = area of opening of outlet, C = co-efficient = 0·6, $\sqrt{h}$ = square root of head of water, Head = the difference of water levels in distributary and watercourse

Example — Design an outlet for 300 acres, 1 cusec being required to irrigate 200 acres, "head" being 2'

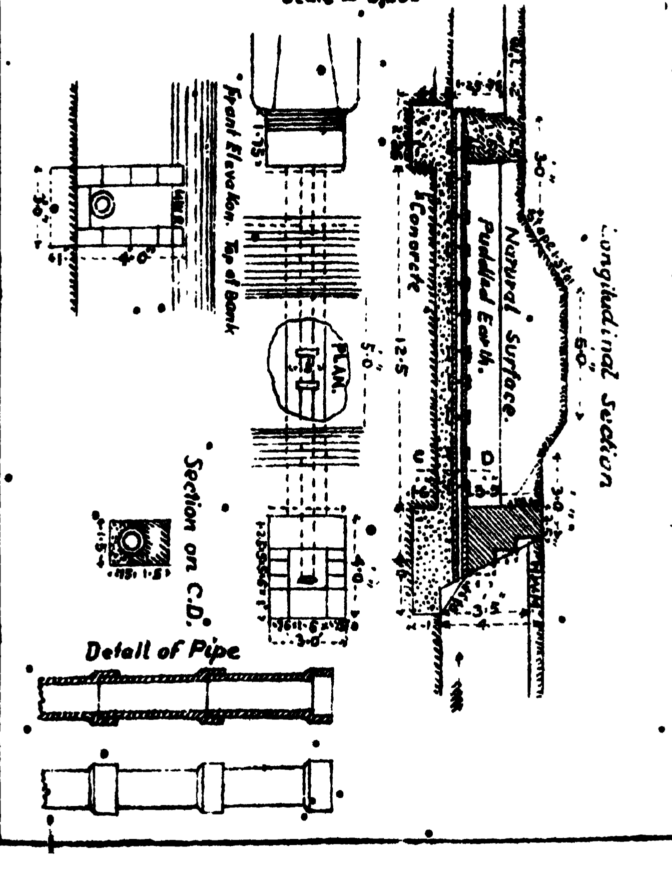
Solution $D = C.A.\sqrt{2gh}$

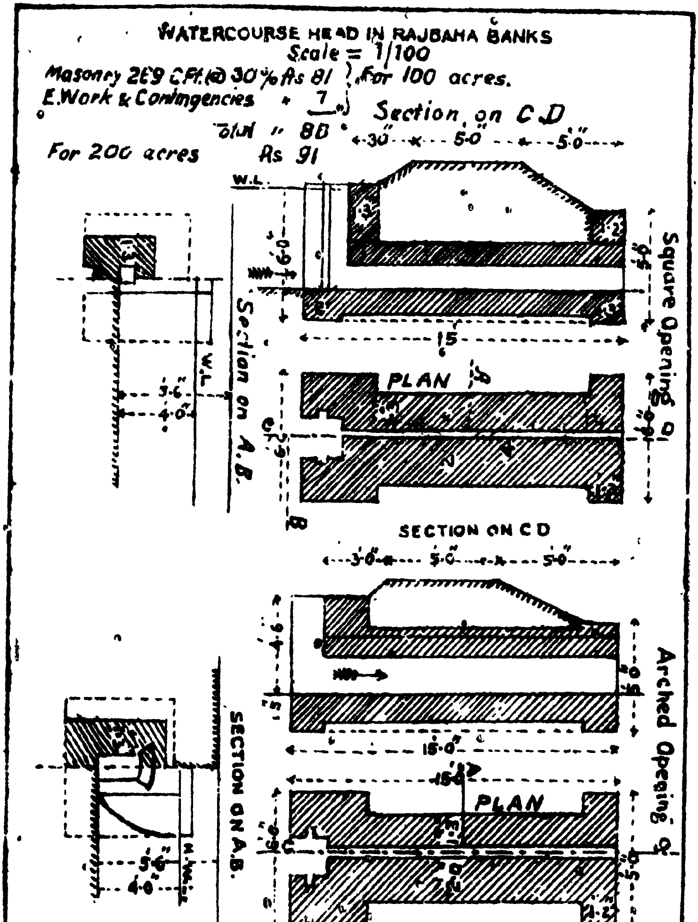
$$\therefore A = \frac{D.}{C.\sqrt{2gh}} = \frac{1{\cdot}5}{{\cdot}6 \times 8 \times \sqrt{h}} = .22;$$

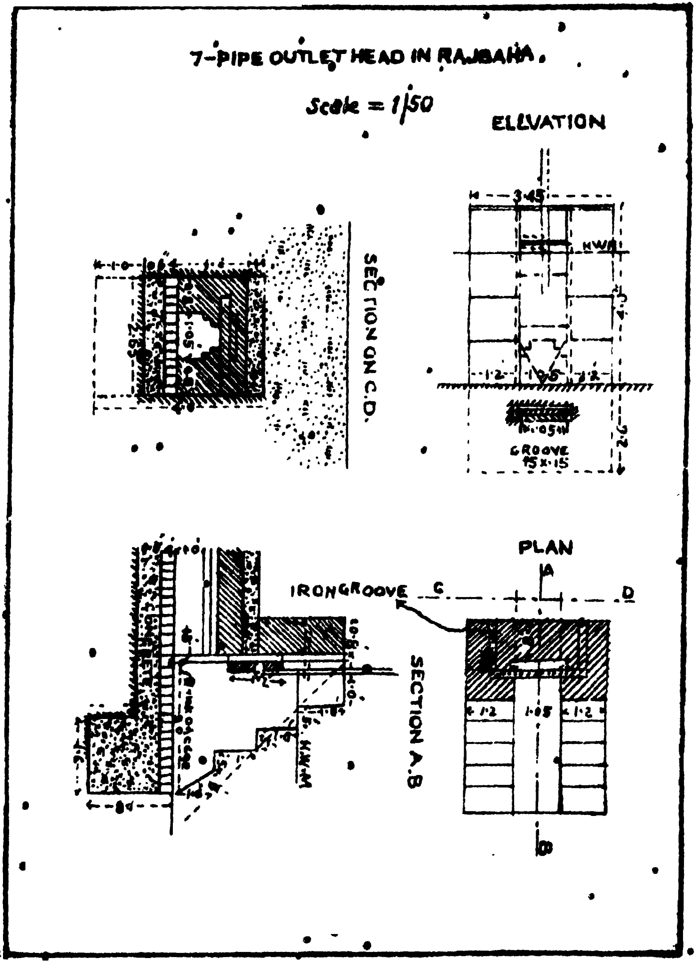
∴ a 2" Outlet (area = ·5 × ·5) will do as per table.

ONE PIPE OUTLET HEAD IN RAJBAHA

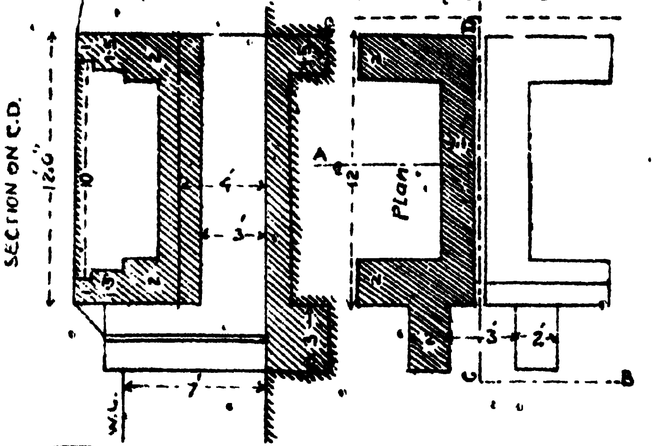
Scale = 3/250




WATERCOURSE HEAD IN RAJBAHA BANKS
Scale = 1/100
Masonry 269 C.Ft. @ 30% Rs 81
E.Work & Contingencies " 7
Total " 88
For 100 acres.
For 200 acres Rs 91
Section on C.D
Section on A.B.
PLAN
Square Opening
SECTION ON CD
SECTION ON A.B.
PLAN
Arched Opening
W.L.
15
15·0"
5·0"
3·0"
3·6"
4·0"

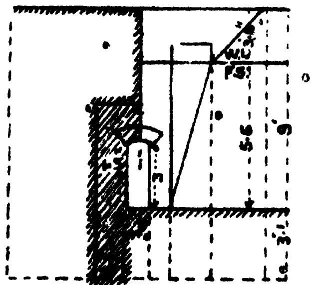

7-PIPE OUTLET HEAD IN RAJBAHA.
Scale = 1/50
ELLVATION
3.45
HWL
1.2
1.05
1.2
GROOVE
15 x 15
SECTION ON C.D.
PLAN
A
IRONGROOVE
C
D
1.2
1.05
1.2
B
SECTION A.B
H.W.M

WATERCOURSE HEAD IN CANAL, SIZE 1'x3'



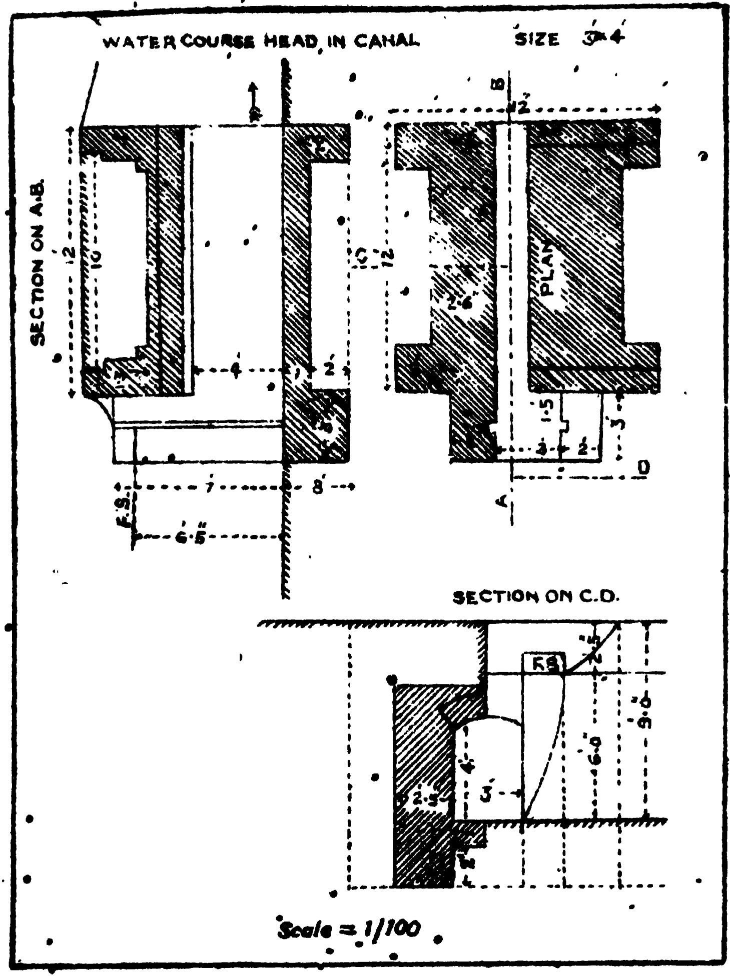
areas to be irrigated	Dimantions of Out let	
	Width	Ht. to Spg.
200	1 - 0"	3'
300	1 · 5"	3'
400	2 - 0"	4'
500	2' - 0"	4'
600	2' - 5"	4
700	2' · 6"	4'
500	2' - 8"	4'
500	2' - 9"	8'
1000	3' - 0"	4'
1100	3' - 0"	4'
1200	3' - 3"	4'
1300	3' - 6"	4'
1400	4 - 0"	4'
1600	5' - 0"	4'

SECTION ON AB.

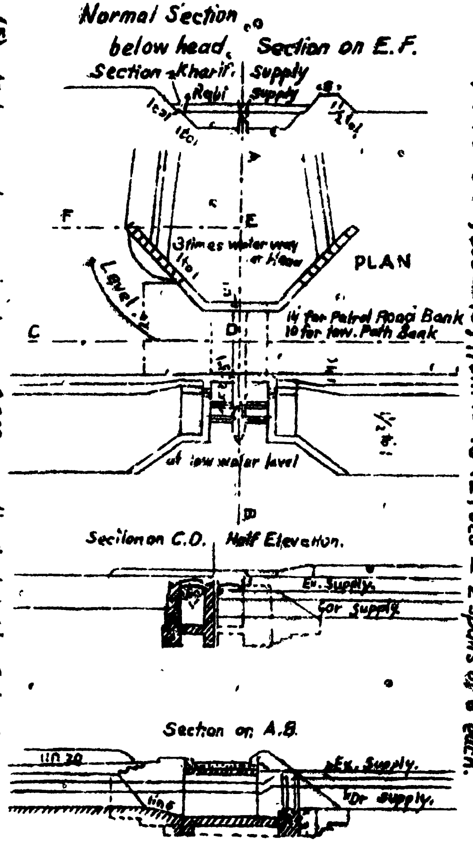


Scale = 1/100

Note.—The sizes of outlets for different areas to be irrigated are fixed as in the adjoined table which has been calculated on the supposition that watercourses will have a bed slope 1 in 5,000 and that 30 acres can be irrigated by one C. ft. of supply.


WATER COURSE HEAD IN CANAL
SIZE 3×4
SECTION ON A.B.
PLAN
SECTION ON C.D.
F.S.
Scale = 1/100

RAJBAHA HEAD



Scale = 1/500

Notes—(1) x = Varies with width of dowel.

(2) The front of first row of karries to be at extraordinary supply level.

(3) No head to be less than 4' wide.

(4) Rajbaha bed below 5' head = 4' wide; Rajbaha bed from 5' to 8' head = 8'; from 3' to 10', bed = 10'; from 10' to 12', bed = 2 spans of 6' each.

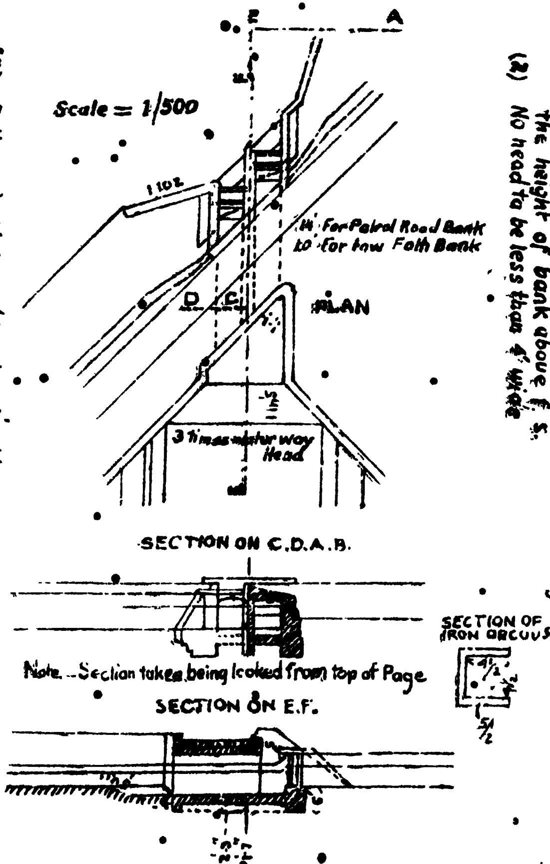
(5) Arches may be semicircular or of 60° according to height of bank above F. S.

(6) All Rajbahas to take out at right angles.

(7) Minimum length of straight portion in the case of ditch rajbahas to be 30'.

(8) Minimum length of R. (the radius of centre line) to be 30'.

SKEW HEAD FOR RAJBAHA



Notes.—(1) Arches may be semicircular or of 60°, according to the height of bank above F. S.

(2) No head to be less than 4' wide.

(3) Rajbaha bed below 5' head = 4' wide; Rajbaha bed from 6' to 8' head = 6'; from 8' to 10', bed = 10'; from 10' to 12', bed = 2 spans of 6' each.

(4) Minimum length of straight portion in the case of ditch rajbahas = 30'.

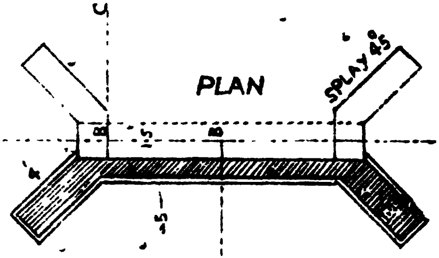
(5) Minimum length of R (the radius of centre line) = 80'.

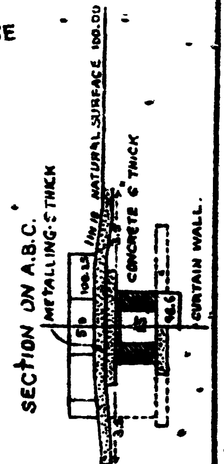
VILLAGE ROAD CULVERT ON WATERCOURSE

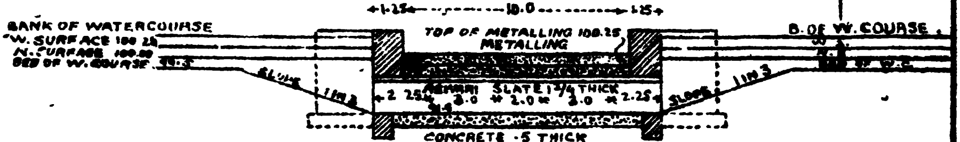
SIZE 1·5×1·5

Scale = 1/100

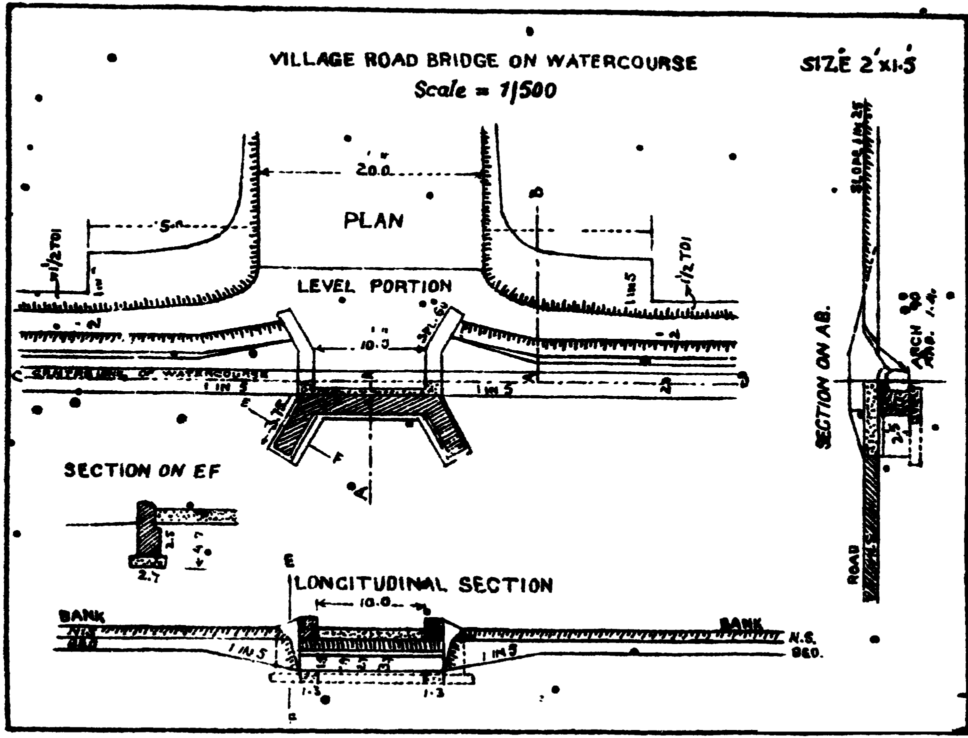
NO OF TYPE	SIZE OF OPENING: WIDTH IN FEET	SIZE OF OPENING: HIGHT IN FEET	SIZE OF OPENING: AREA IN SQ. FEET	THICKNESS OF ABUTMENT IN FEET	WIDTH OF SLATE IN FEET	THICKNESS OF SLATE IN INCHES
I	1.00	1.00	1.00	0.8	1.5	1½
II	1.25	1.00	1.25	0.8	1.75	1½
III	1.25	1.25	1.56	0.8	1.75	1½
IV	1.5	1.25	1.86	0.8	2.00	1¾
V	1.5	. 6	2.25	0.8	2.00	1¾
VI	1.75	1.5	2.63	0.8	2.25	1¾
VII	1.75	1.75	3.10	1.3	2.25	1¾
VIII	2.0	1.75	3.5	1.3	2.25	2
IX	2.0	2.0	4.0	1.3	2.5	2

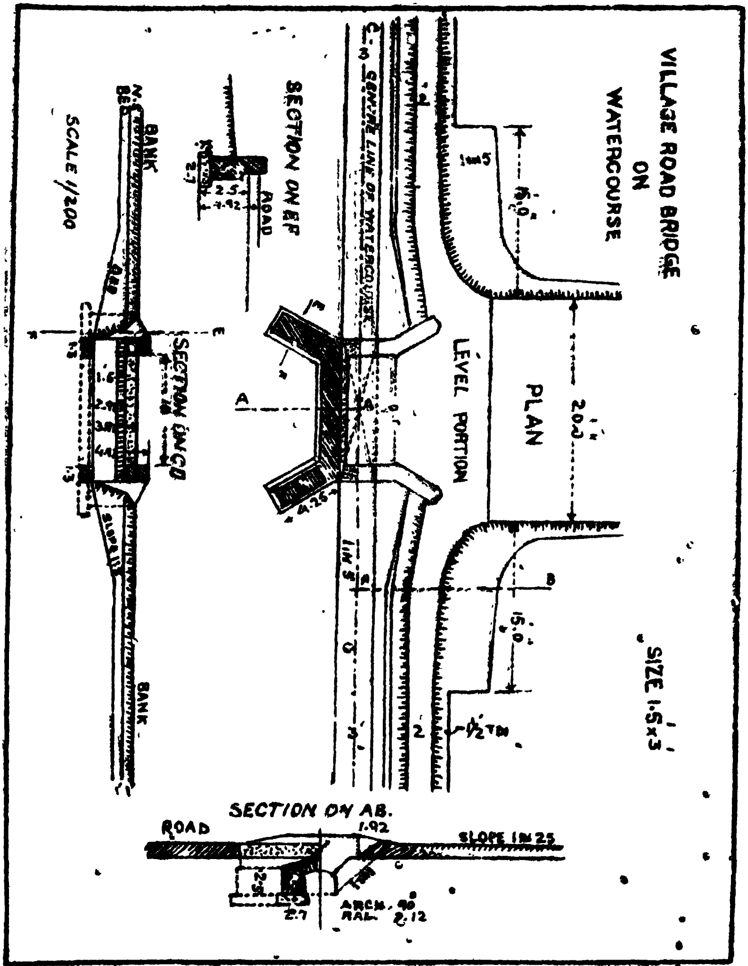






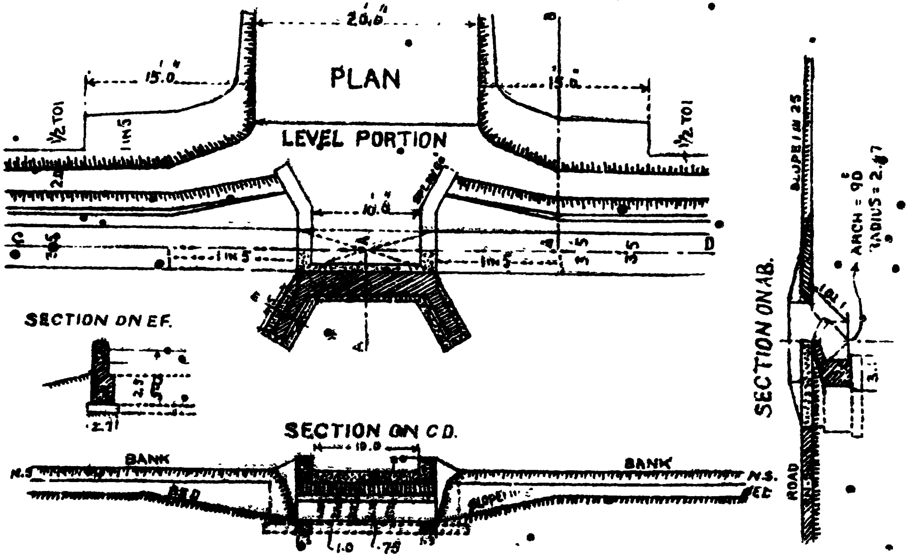
Note:—*Velocity assumed through culvert is 1 foot per second.*

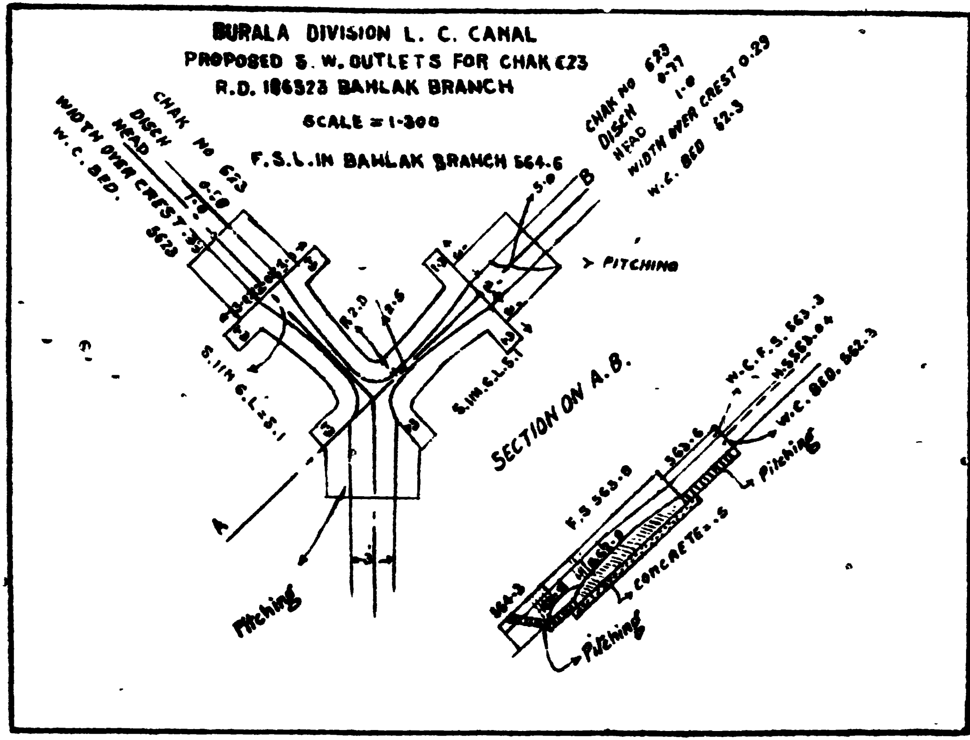

VILLAGE ROAD BRIDGE ON WATERCOURSE
Scale = 1/500
SIZE 2'x1.5'
PLAN
20.0
5.0
1½ TO 1
1 in 5
LEVEL PORTION
10.0
1 in 5
SPL. 6.0
SECTION ON EF
2.5
2.7
4.7
LONGITUDINAL SECTION
10.0
BANK
N.S.
BED.
1.3
SECTION ON AB.
ROAD
SLOPE 1 IN 25
ARCH
RAD. 1.4

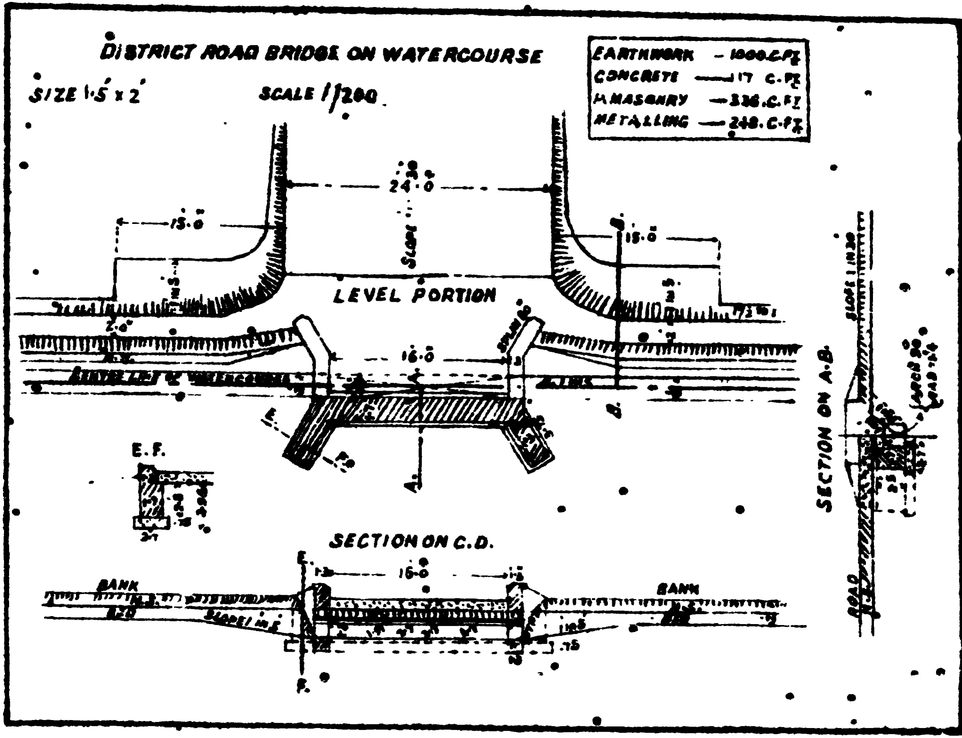

VILLAGE ROAD BRIDGE
ON
WATERCOURSE
SIZE 1.5×3
PLAN
LEVEL PORTION
CENTRE LINE OF WATERCOURSE
SECTION ON EF
ROAD
SECTION ON CD
BANK
SCALE 1/200
SECTION ON AB.
ROAD
SLOPE IN 25
ARCH. 90
RAL. 2.12

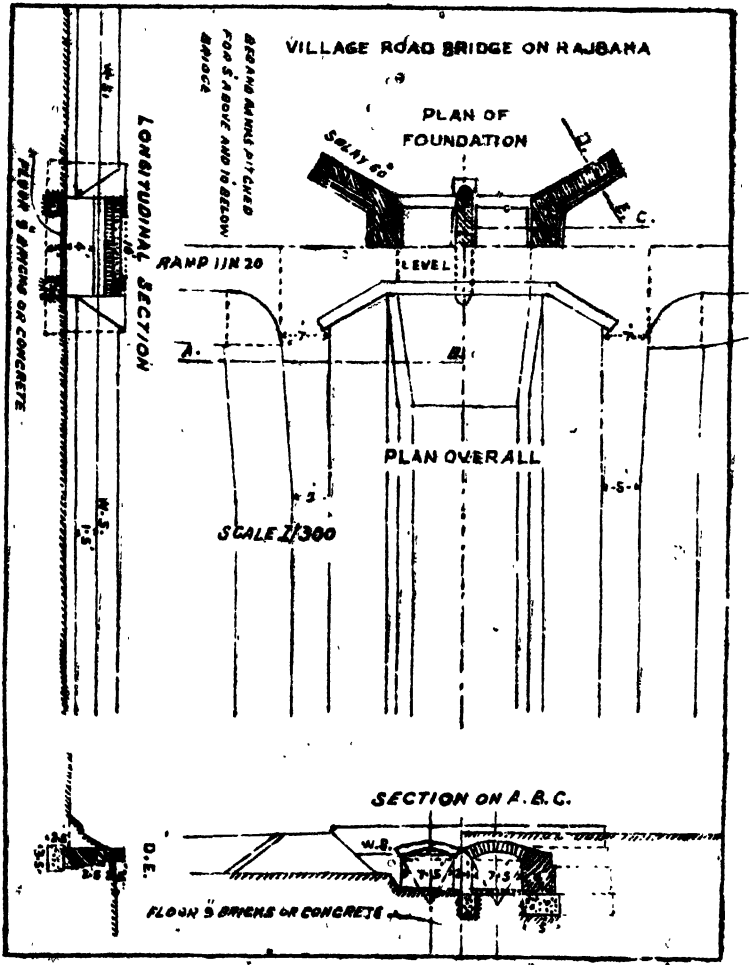
VILLAGE ROAD BRIDGE ON WATERCOURSE. SIZE 1·75x3·5

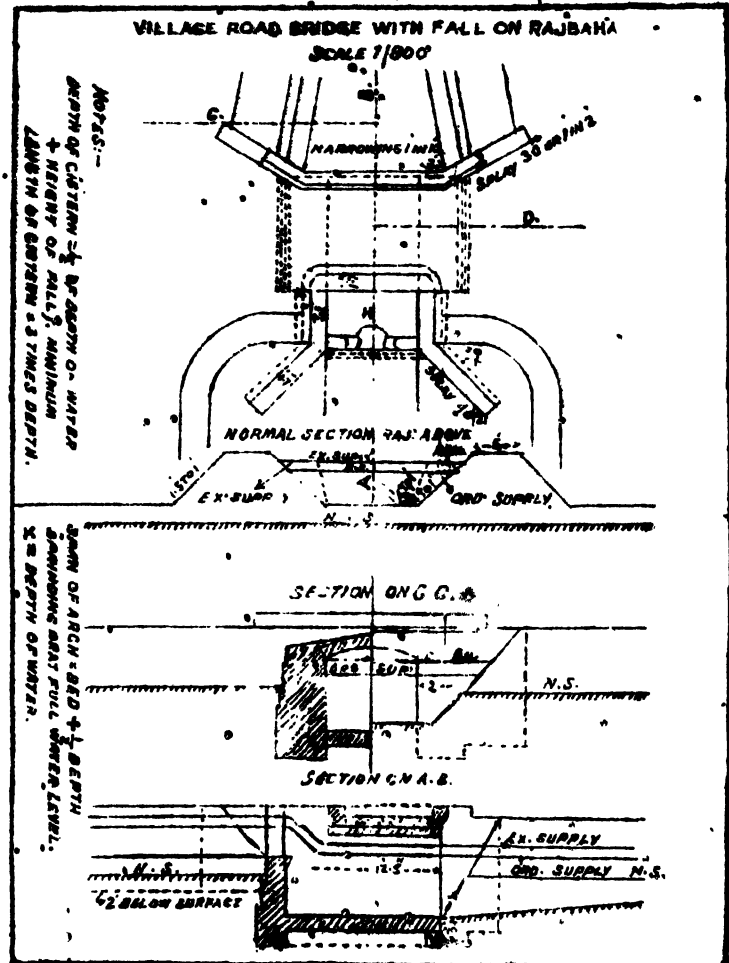
SCALE = 1/200

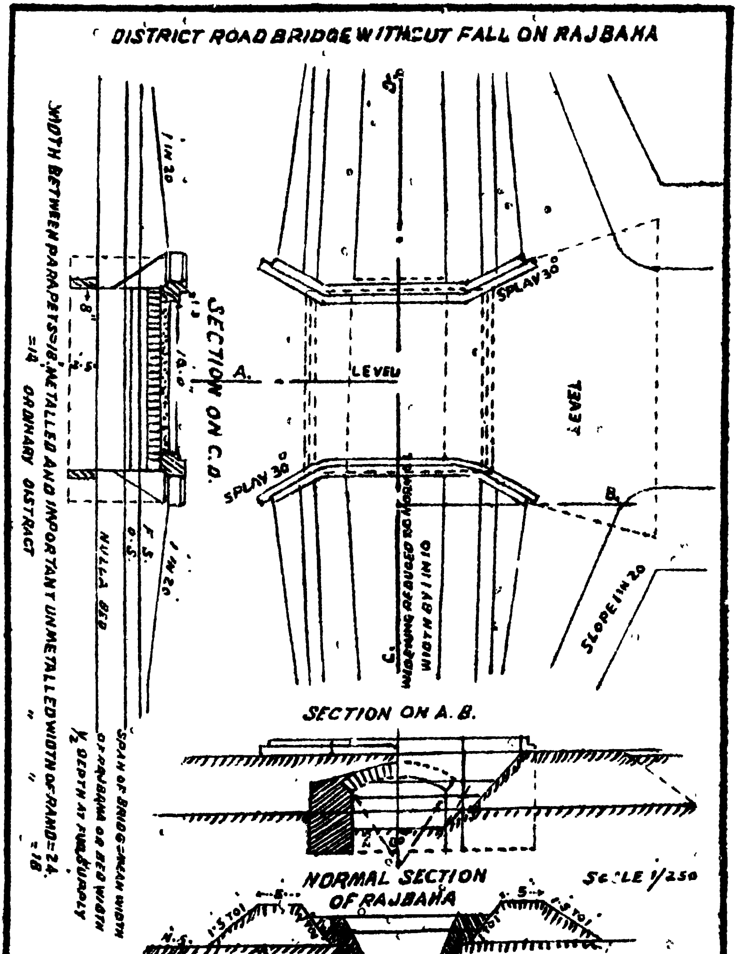



BURALA DIVISION L. C. CANAL
PROPOSED S. W. OUTLETS FOR CHAK 623
R.D. 186523 BAHLAK BRANCH
SCALE = 1-300
F.S.L. IN BAHLAK BRANCH 564.6
CHAK NO 623
DISCH 0.58
HEAD 1.8
WIDTH OVER CREST .33
W.C. BED. 562.3
CHAK NO 623
DISCH 0.77
HEAD 1.8
WIDTH OVER CREST 0.29
W.C. BED 62.3
A
B
R 2.0
2.5
5.0
S.1 IN G.L.= 5.1
S.1 IN G.L.S.1
PITCHING
Pitching
SECTION ON A.B.
F.S 563.0
563.6
564.3
CONCRETE = .5
W.C.F.S. 563.3
W.S 562.04
W.C. BED. 562.3
Pitching
Pitching

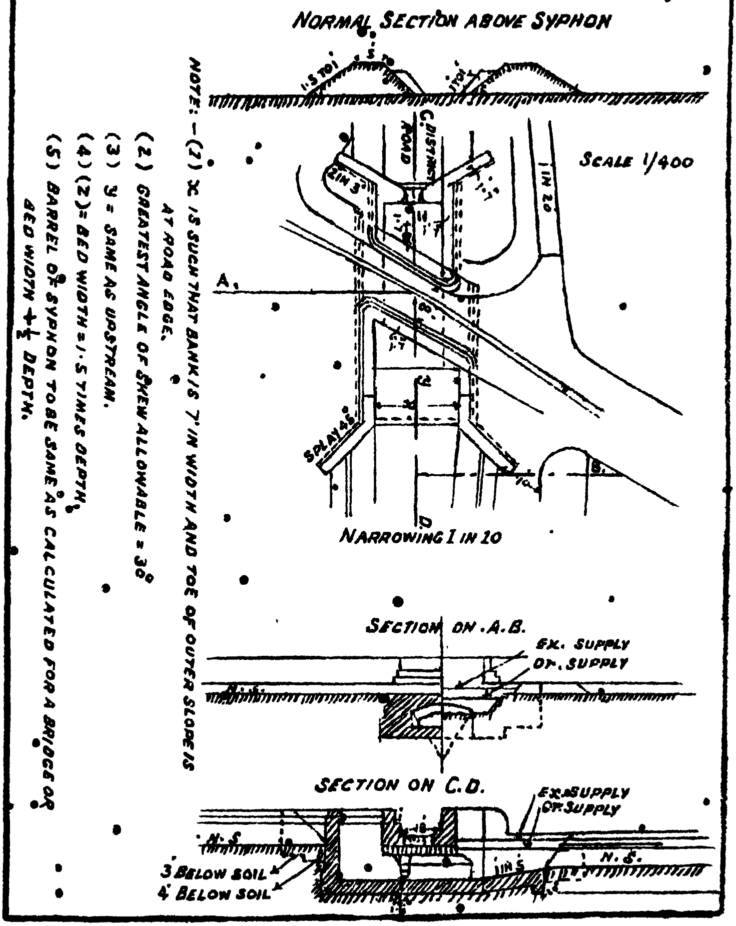

DISTRICT ROAD BRIDGE ON WATERCOURSE
SIZE 1·5' x 2'
SCALE 1/200
EARTHWORK - 1000 C.FT
CONCRETE - 17 C.FT
MASONRY - 336 C.FT
METALLING - 248 C.FT
24·0
15·0
SLOPE
LEVEL PORTION
16·0
E.F.
SECTION ON C.D.
BANK
SLOPE 1 IN 6
SECTION ON A.B.
SLOPE 1 IN 30
ROAD


VILLAGE ROAD BRIDGE ON RAJBAHA
PLAN OF FOUNDATION
PLAN OVERALL
RAMP 1 IN 20
LEVEL
SCALE 1/300
LONGITUDINAL SECTION
FLOOR 9" BRICKS OR CONCRETE
SECTION ON A.B.C.
FLOOR 9" BRICKS OR CONCRETE
D.E.

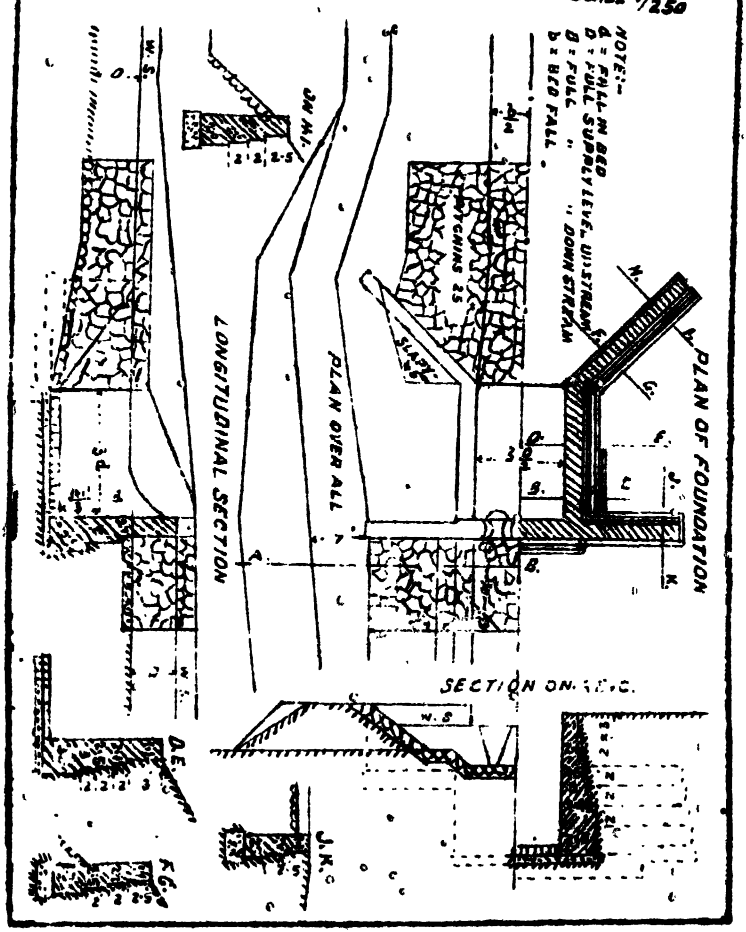

VILLAGE ROAD BRIDGE WITH FALL ON RAJBAHA
SCALE 1/800
NOTES:-
DEPTH OF CISTERN = 1/4 OF DEPTH OF WATER + HEIGHT OF FALL, 6" MINIMUM
LENGTH OF CISTERN = 3 TIMES DEPTH.
SPAN OF ARCH = BED + 1/2 DEPTH
SPRINGING AT FULL WATER LEVEL.
X = DEPTH OF WATER.
NARROWING 1 IN 3
SPLAY 30 or 1 IN 2
C.
D.
NORMAL SECTION RAJ. ABOVE
EX. SUPP.
ORD. SUPPLY
N.S.
SECTION ON C D.
SECTION ON A.B.
EX. SUPPLY
ORD. SUPPLY
BELOW SURFACE


DISTRICT ROAD BRIDGE WITHOUT FALL ON RAJBAHA
SECTION ON C.D.
SPLAY 30°
LEVEL
SLOPE 1 IN 20
SECTION ON A. B.
NORMAL SECTION OF RAJBAHA
SCALE 1/250
1 IN 20
NULLA BED
SPAN OF BRIDGE=MEAN WIDTH OF RAJBAHA OR BED WIDTH
½ DEPTH AT FULL SUPPLY
WIDTH BETWEEN PARAPETS=18, METALLED AND IMPORTANT UNMETALLED WIDTH OF RAMP=24
=14 ORDINARY DISTRACT =18
WIDTH REDUCED BY 1 IN 10
WARNING REDUCED OR OPENING
1.5 TO 1
N.S.

DISTRICT ROAD BRIDGE SKEW WITH FALL ON RAJBAHA

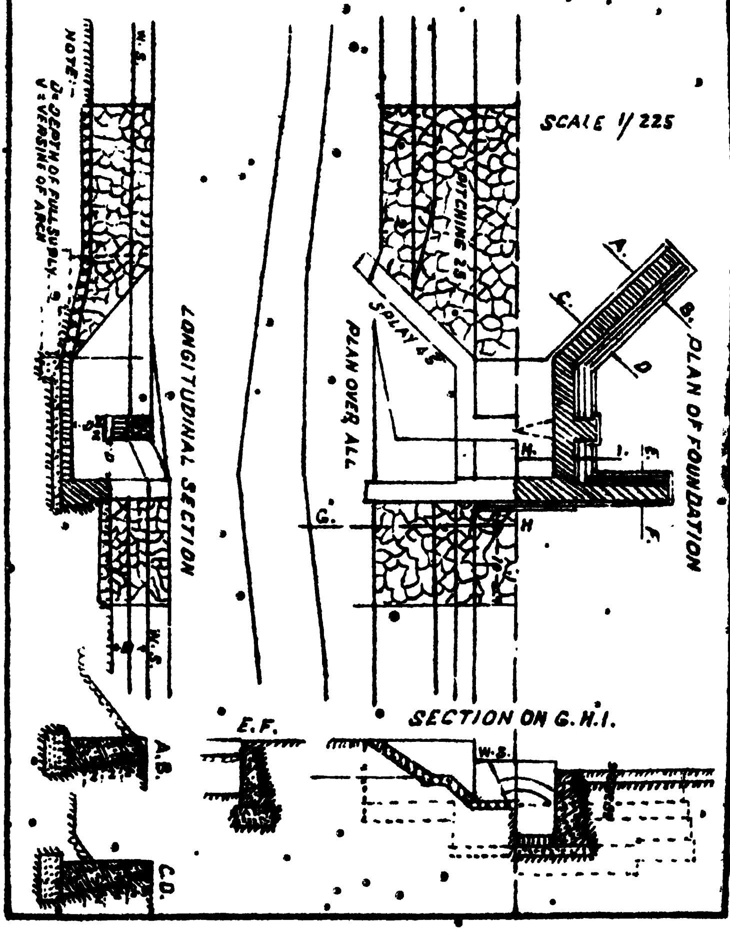


FALL (COMPLETE)

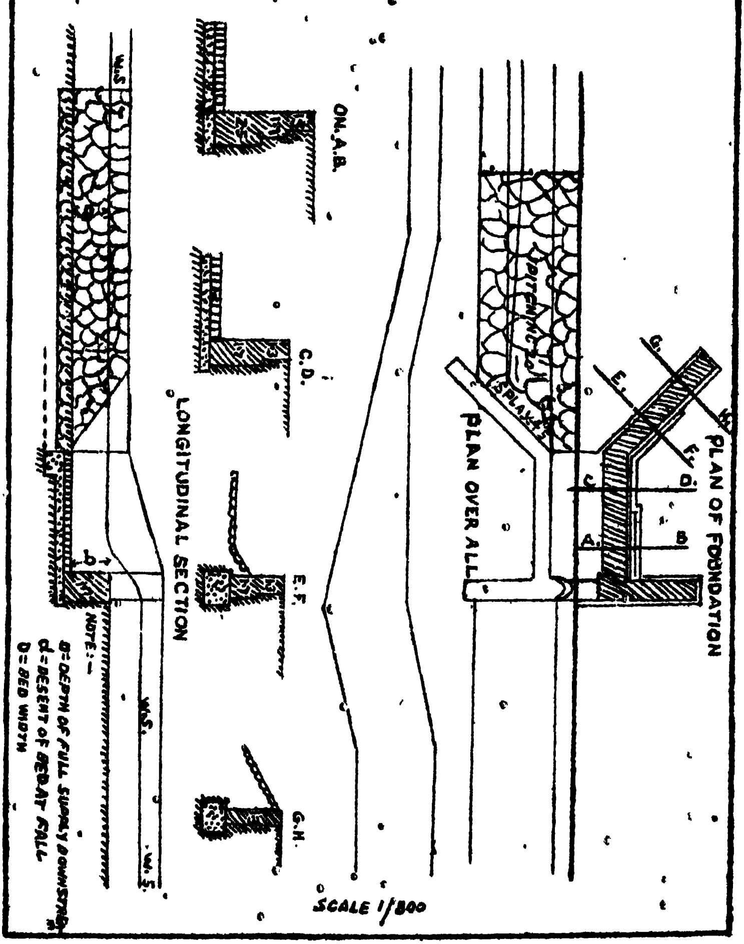


805

FALL INCOMPLETE

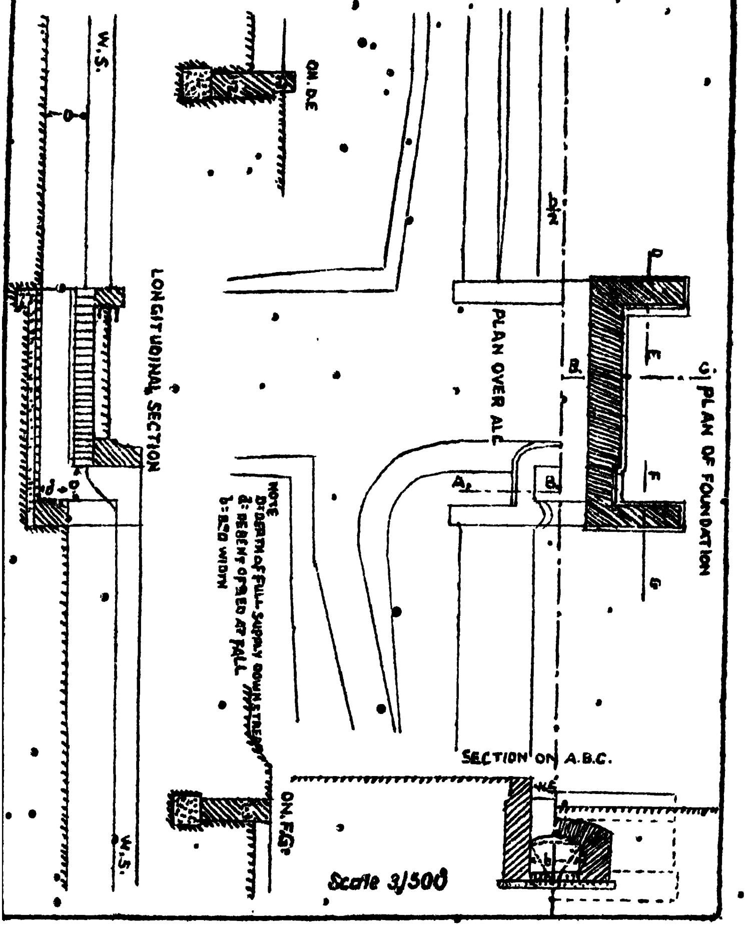


MINOR FALL (COMPLETE)

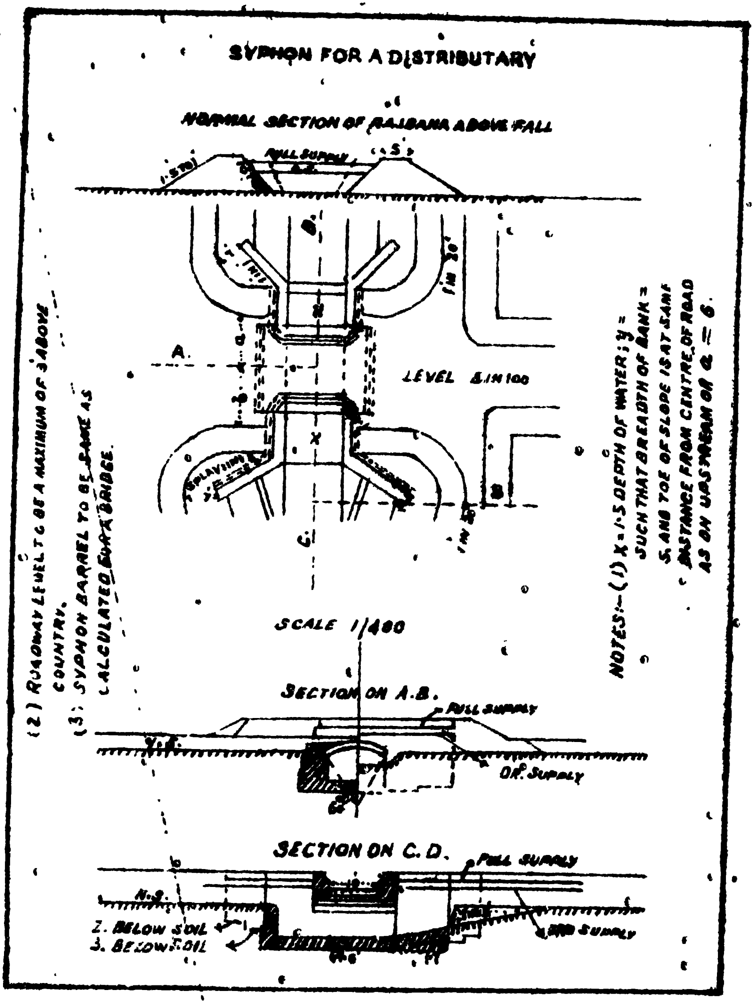


SCALE 1/800

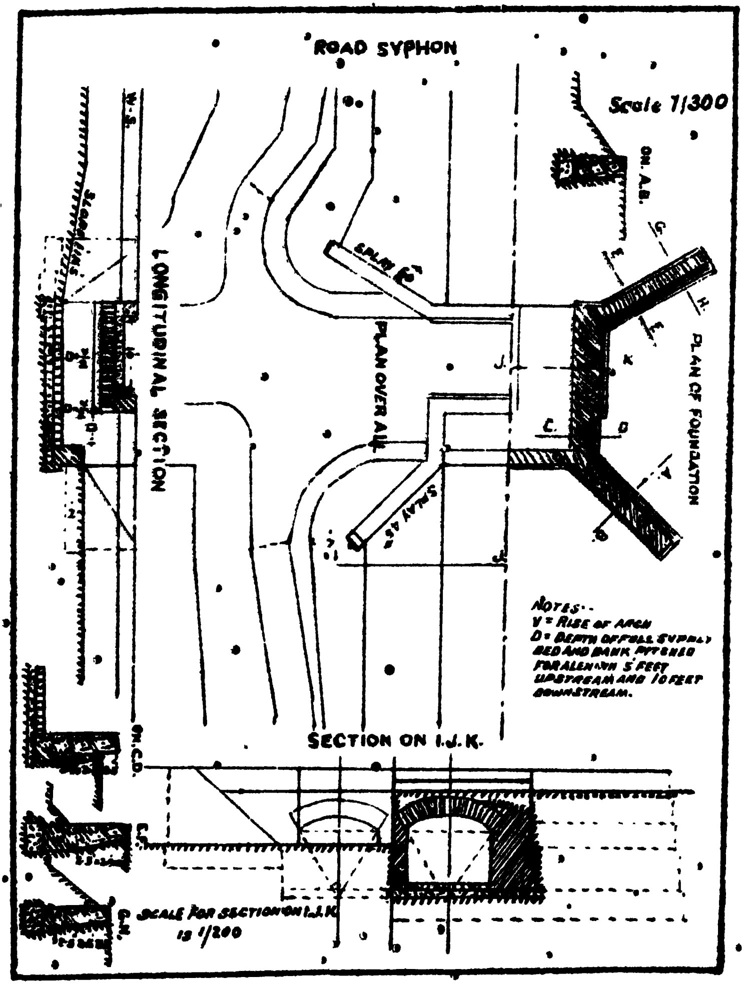
MINOR FALL (INCOMPLETE)



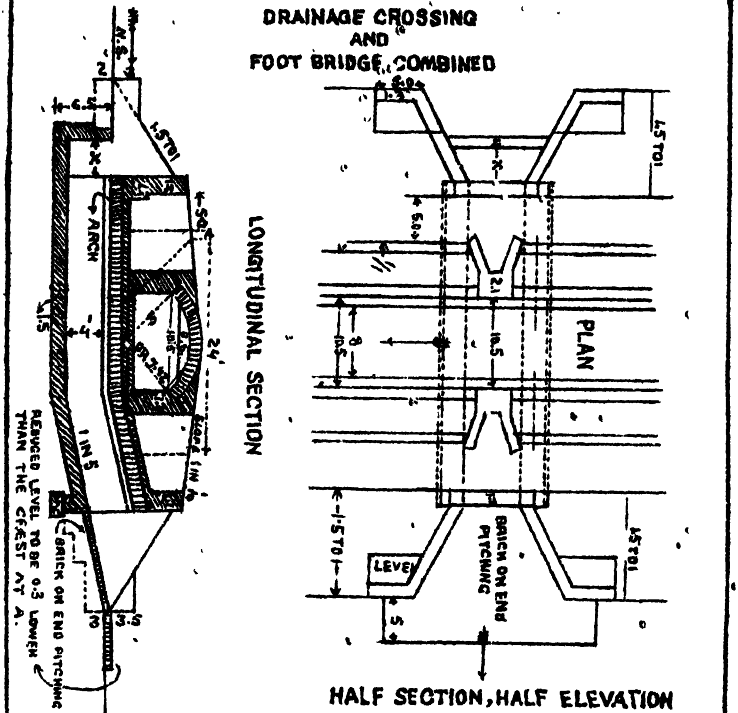
Scale 3/500

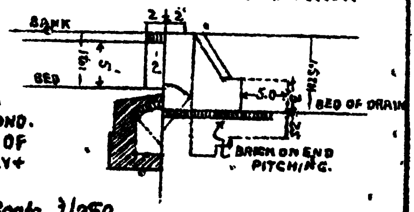


SYPHON FOR A DISTRIBUTARY
NORMAL SECTION OF RAJBAHA ABOVE FALL
FULL SUPPLY
LEVEL 2 IN 100
SCALE 1/480
SECTION ON A.B.
FULL SUPPLY
SECTION ON C.D.
FULL SUPPLY
2. BELOW SOIL
3. BELOW SOIL
(2) ROADWAY LEVEL TO BE A MAXIMUM OF 3 ABOVE COUNTRY.
(3) SYPHON BARREL TO BE SAME AS CALCULATED FOR A BRIDGE.
NOTES:- (1) X = 1·5 DEPTH OF WATER; y = SUCH THAT BREADTH OF BANK = S, AND TOE OF SLOPE IS AT SAME DISTANCE FROM CENTRE OF ROAD AS ON UPSTREAM OR a = 6


ROAD SYPHON
Scale 1/300
ON A.B.
LONGITUDINAL SECTION
PLAN OVER ALL
PLAN OF FOUNDATION
SPLAY 45°
NOTES:-
V = RISE OF ARCH
D = DEPTH OF FULL SUPPLY
BED AND BANK PITCHED
FOR A LENGTH 5 FEET
UPSTREAM AND 10 FEET
DOWNSTREAM.
SECTION ON I.J.K.
ON C.D.
SCALE FOR SECTION ON I.J.K.
IS 1/200

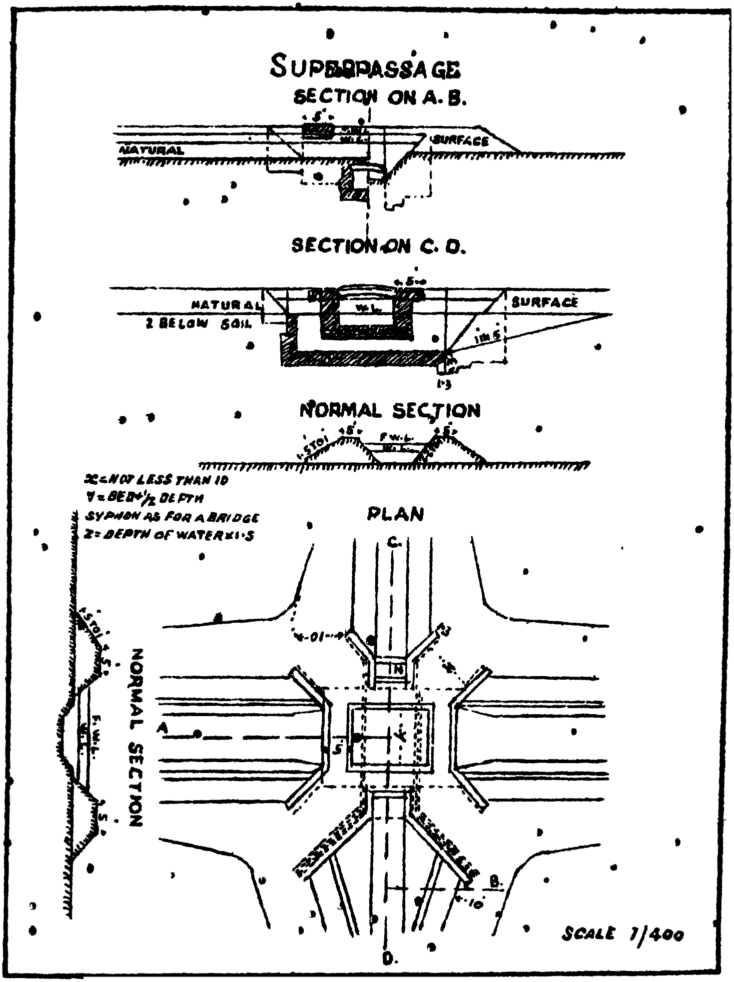
DRAINAGE CROSSING AND FOOT BRIDGE COMBINED





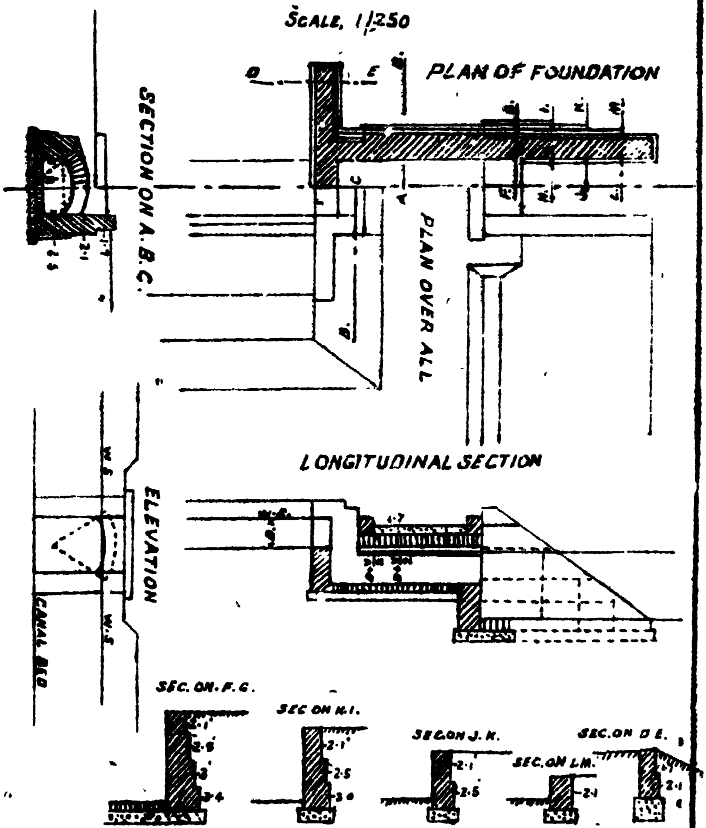
NOTES:—
X = HEIGHT OF BARREL.
BARREL TO HAVE AN AREA AS REQUIRED FOR DISCHARGE AT A MEAN VELOCITY OF 3' PER SECOND.
WIDTH OF FOOT BRIDGE = SPAN OF BRIDGE = BED OF DISTRIBUTARY + ½ DEPTH OF FULL SUPPLY.

Scale, 1/250

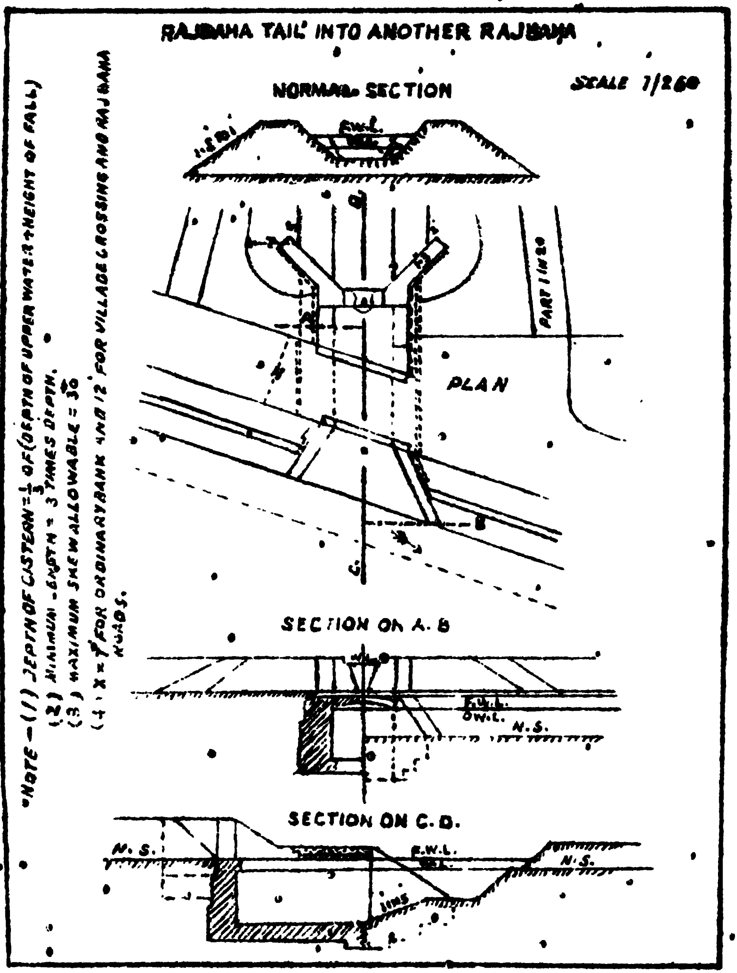

SUPERPASSAGE
SECTION ON A. B.
NATURAL
SURFACE
SECTION ON C. D.
NATURAL
2 BELOW SOIL
SURFACE
1 IN 5
NORMAL SECTION
F.W.L.
W.L.
x = NOT LESS THAN 10
Y = BED + 1/2 DEPTH
SYPHON AS FOR A BRIDGE
Z = DEPTH OF WATER x 1·5
PLAN
NORMAL SECTION
SCALE 1/400

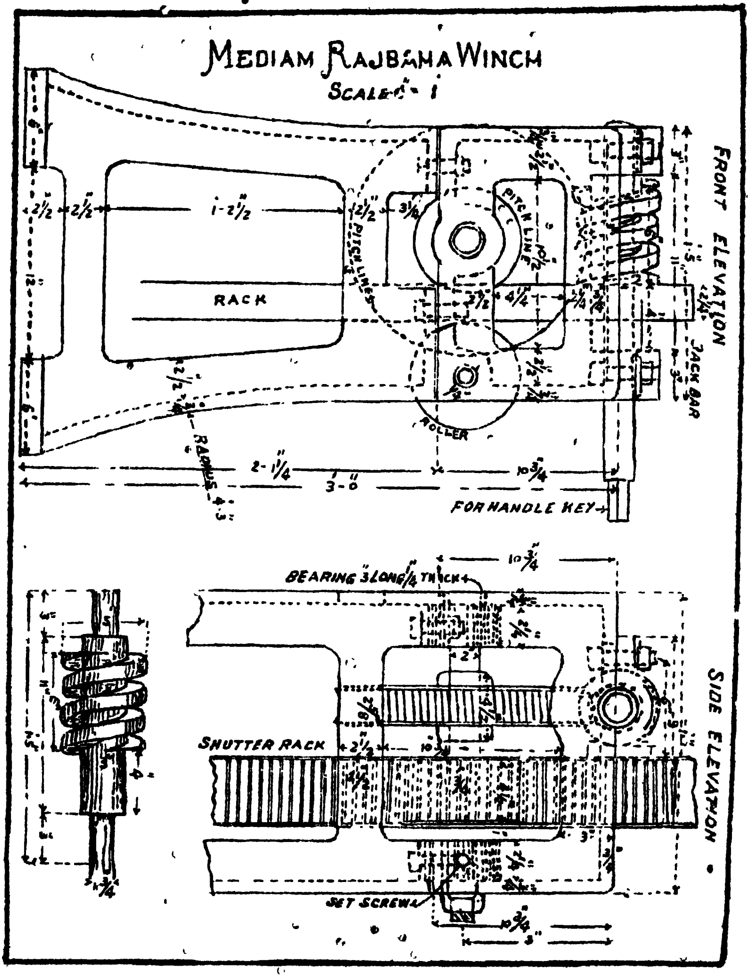
RAJBANA TAIL INTO CANAL

Scale, 1/250



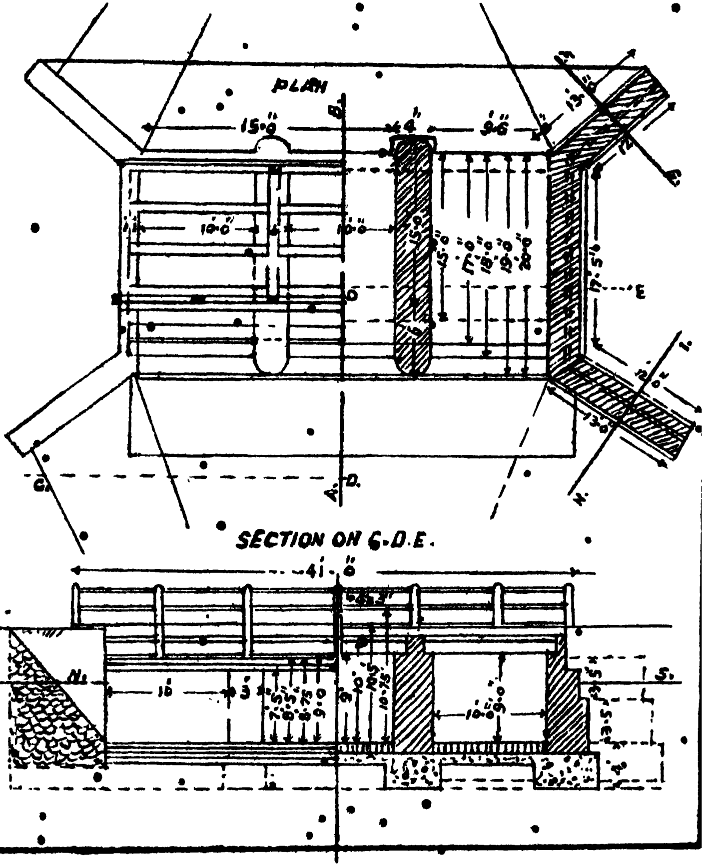
NOTE:—
D = FULL SUPPLY IN RAJBANA
Y = RISE OF ARCH
t = THICKNESS OF ARCH
b = BED WIDTH OF RAJBANA

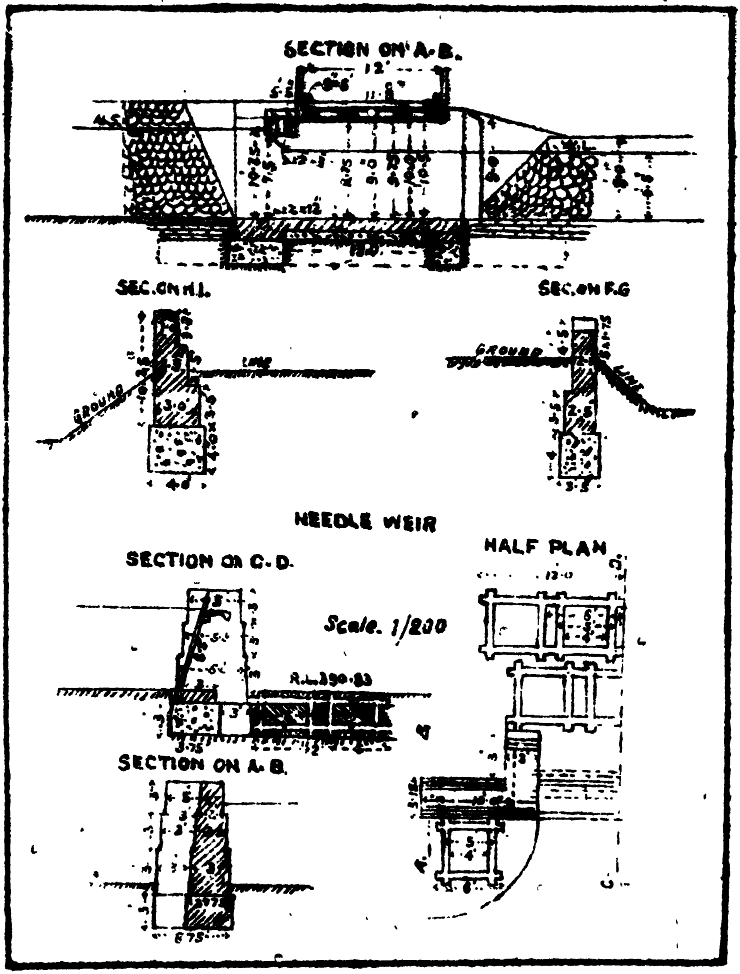

RAJBAHA TAIL INTO ANOTHER RAJBAHA
NORMAL SECTION
SCALE 1/260
F.S.L.
F.W.L.
PART 1 IN 20
PLAN
SECTION ON A.B
F.W.L.
O.W.L.
N.S.
SECTION ON C.D.
N.S.
F.W.L.
N.S.
NOTE—(1) DEPTH OF CISTERN = 1/3 OF (DEPTH OF UPPER WATER + HEIGHT OF FALL)
(2) MINIMUM LENGTH = 3 TIMES DEPTH.
(3) MAXIMUM SKEW ALLOWABLE = 30
(4) X = 7' FOR ORDINARY BANK AND 12' FOR VILLAGE CROSSING AND RAJBAHA ROADS.


MEDIAM RAJBAHA WINCH
SCALE ¼" = 1
FRONT ELEVATION
RACK
PITCH LINES
PITCH LINE
ROLLER
RADIUS
JACK BAR
FOR HANDLE KEY
2-1¼
3-0
10¾
SIDE ELEVATION
BEARING 3 LONG ¼ THICK
SHUTTER RACK
SET SCREW

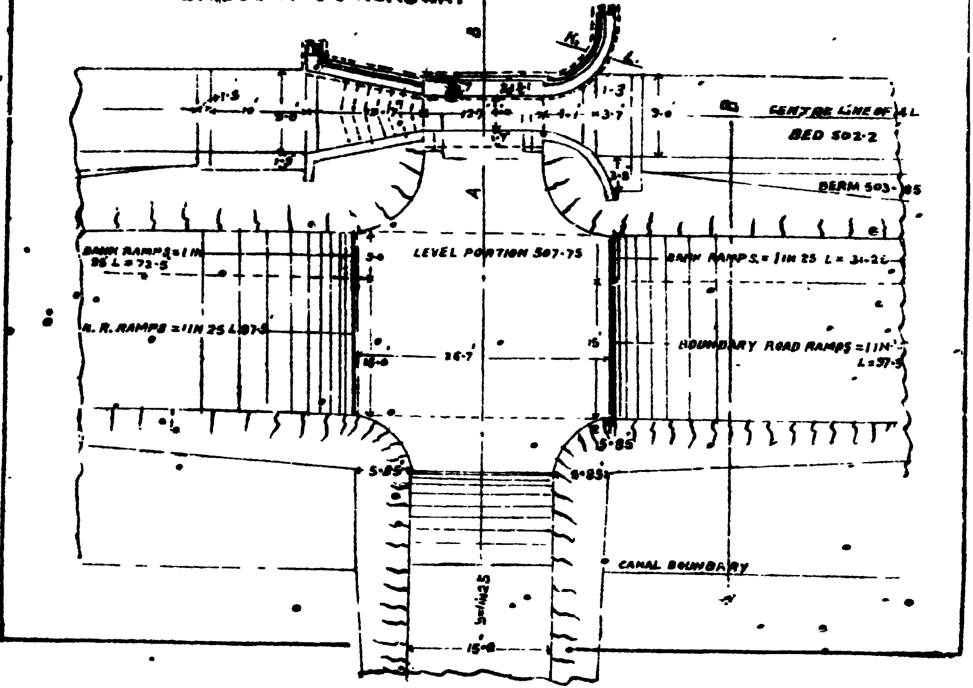
NEEDLE REGULATOR AND BRIDGE

SCALE 1/200

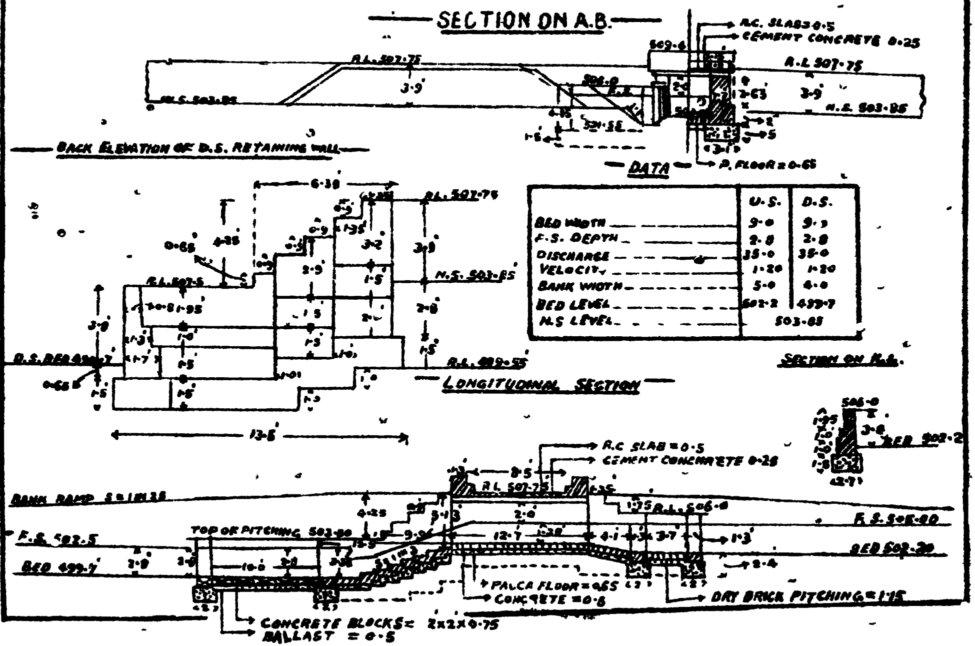



SECTION ON A.B.
SEC. ON H.I.
SEC. ON F.G
GROUND
LINE
NEEDLE WEIR
SECTION ON C.D.
HALF PLAN
Scale. 1/200
R.L. 390.83
SECTION ON A.B.

PLAN OF 2·6 FALL
WITH V. R. BRIDGE OF 9·5 ROADWAY



DETAILS OF 2·5' FALL WITH V. R. BRIDGE ON PAGE. 817

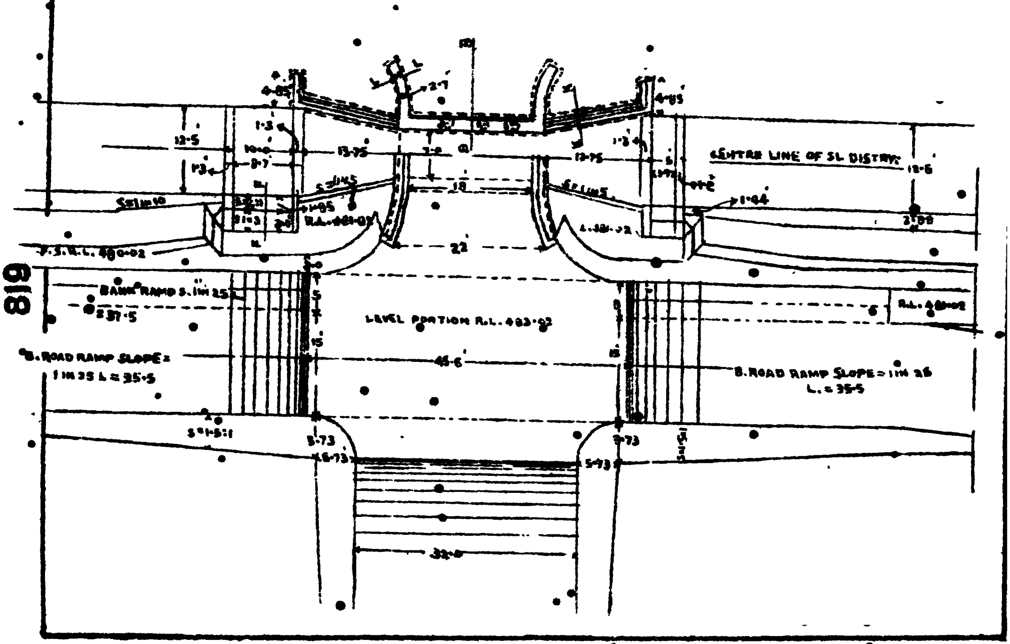


DATA

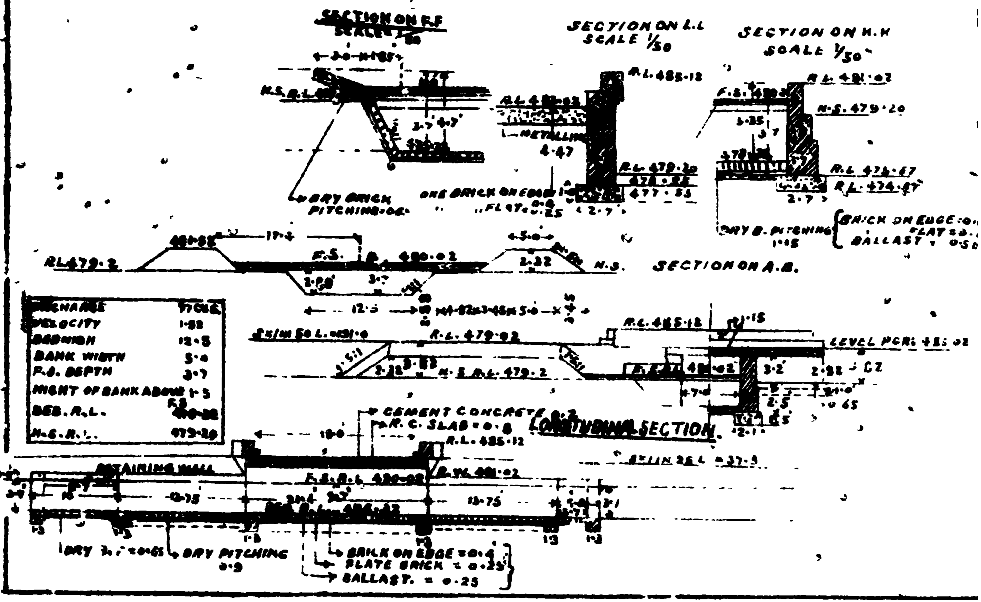
	U.S.	D.S.
BED WIDTH	9·0	9·3
F.S. DEPTH	2·8	2·8
DISCHARGE	35·0	35·0
VELOCITY	1·20	1·20
BANK WIDTH	5·0	4·0
BED LEVEL	502·2	499·7
H.S LEVEL	503·85	

PLAN OF ARTERIAL ROAD BRIDGE,

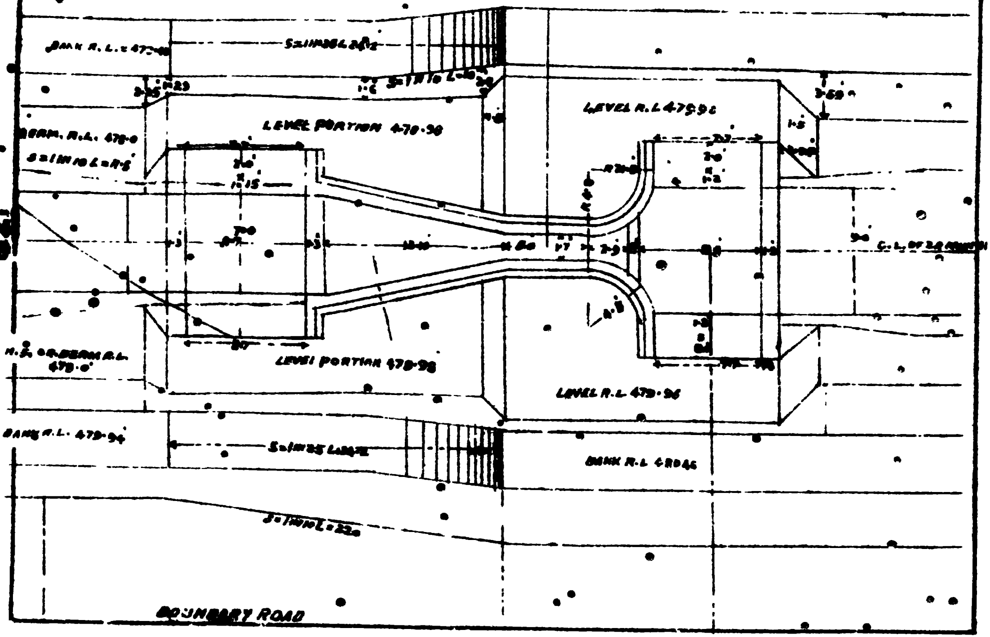
TO BE BUILT AT A DISTY.



DETAILS OF ARTERIAL ROAD BRIDGE ON PAGE 219

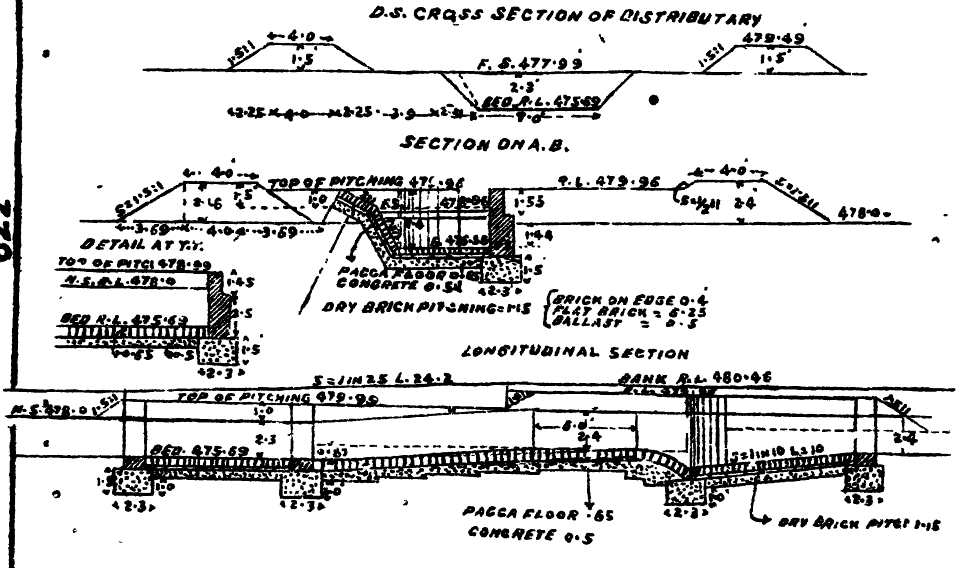


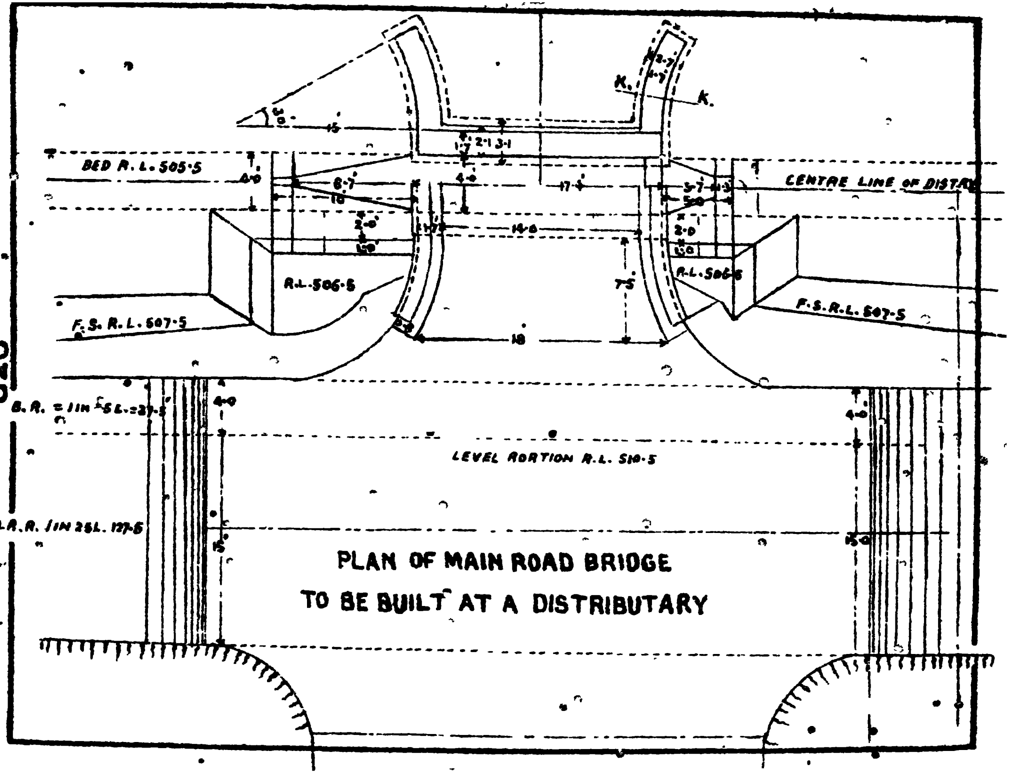
PLAN OF 0·97' FALL
TO BE BUILT AT A MINOR.



DETAILS OF 0·97 FALL OF A MINOR.

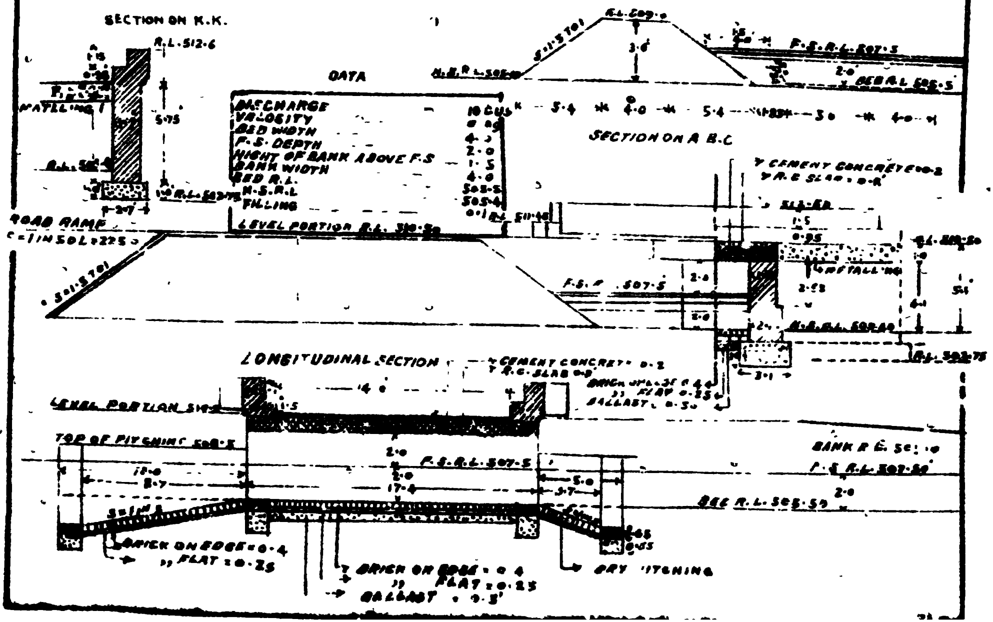
ON PAGE. 821

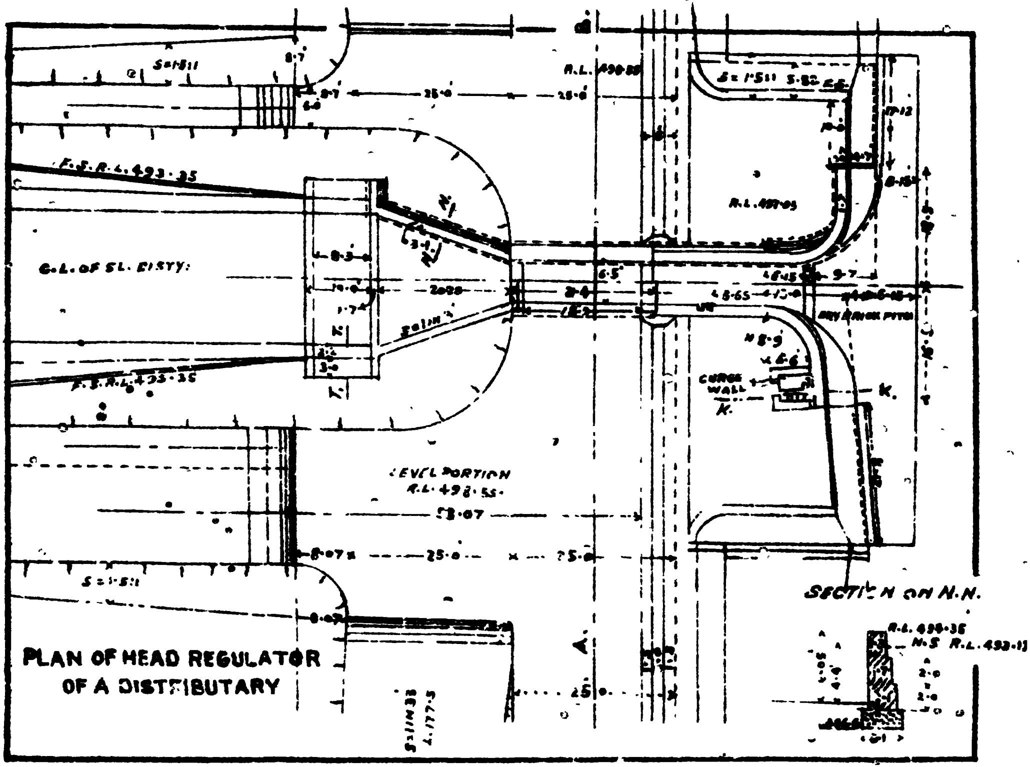




PLAN OF MAIN ROAD BRIDGE TO BE BUILT AT A DISTRIBUTARY

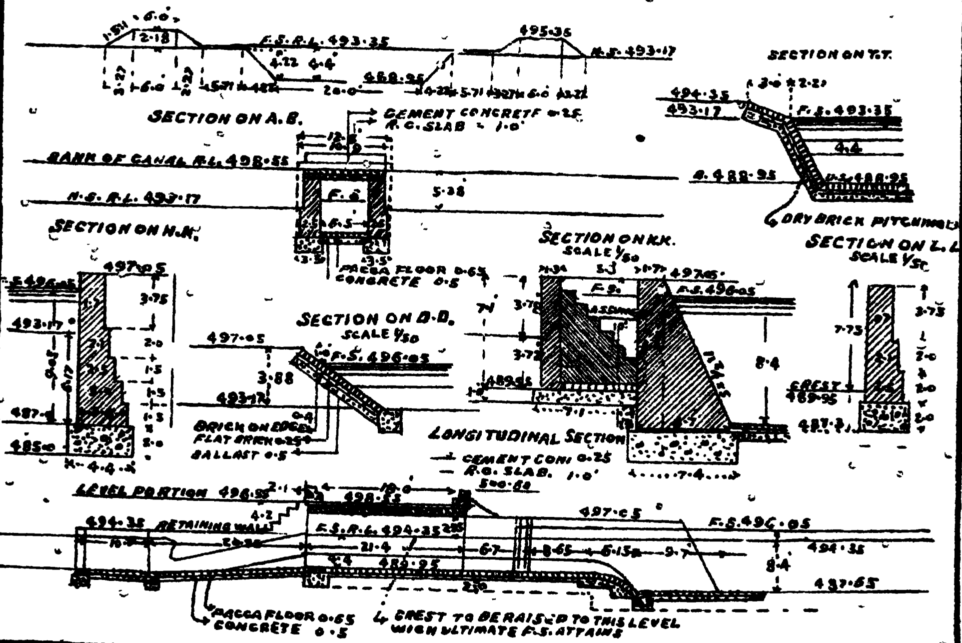
DETAILS OF MAIN ROAD BRIDGE.
ON PAGE 823

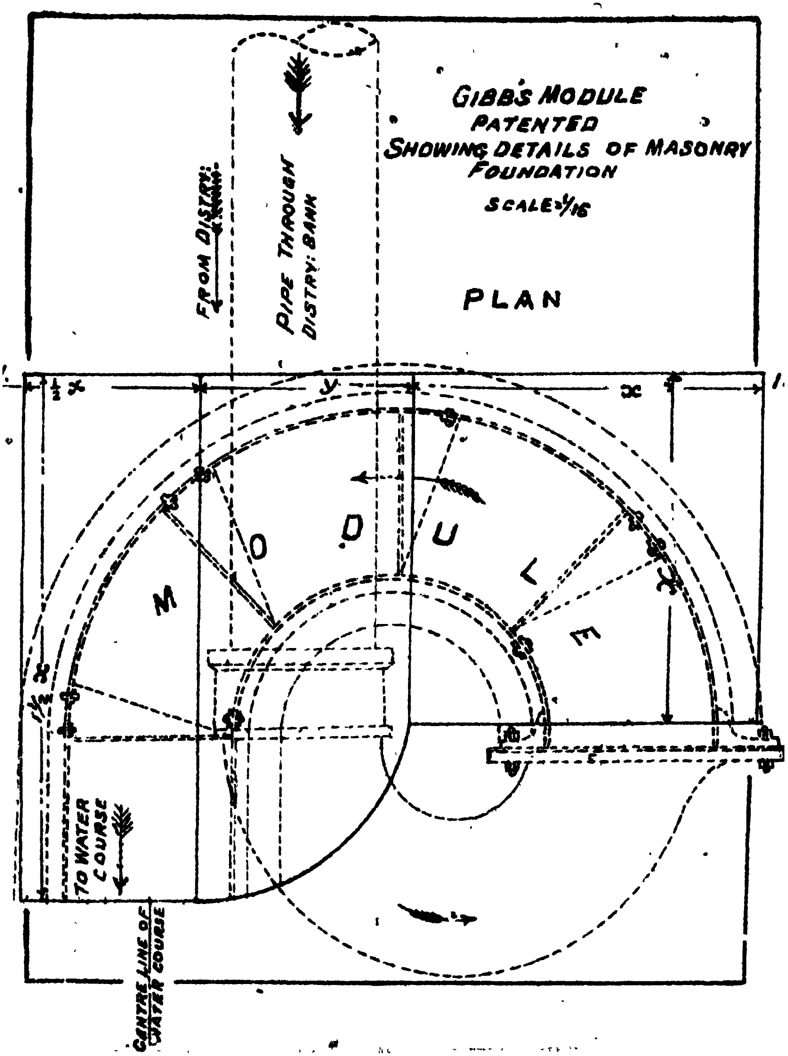




PLAN OF HEAD REGULATOR
OF A DISTRIBUTARY

DETAILS OF HEAD REGULATOR.
ON PAGE. 825




GIBB'S MODULE
PATENTED
SHOWING DETAILS OF MASONRY
FOUNDATION
SCALE=1/16
PLAN
FROM DISTRY:
PIPE THROUGH
DISTRY: BANK
MODULE
TO WATER
COURSE
CENTRE LINE OF
WATER COURSE

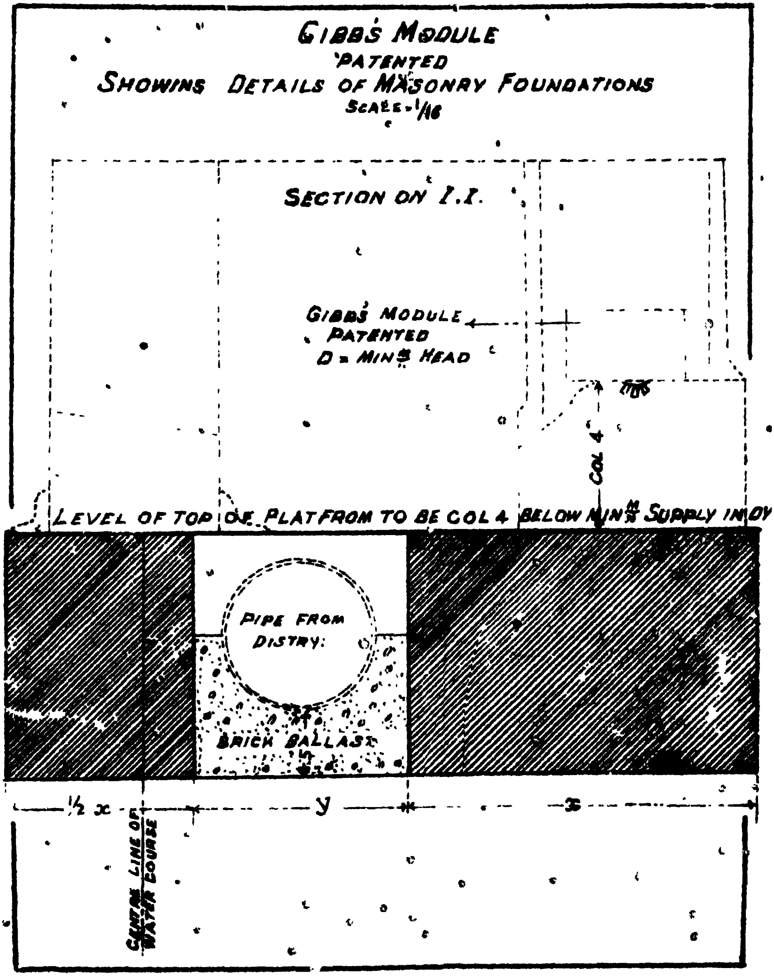
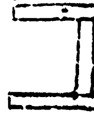
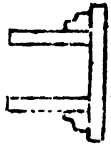

GIBB'S MODULE
PATENTED
SHOWING DETAILS OF MASONRY FOUNDATIONS
SCALE - 1/16
SECTION ON I.I.
GIBB'S MODULE
PATENTED
D = MINM HEAD
COL 4
LEVEL OF TOP OF PLATFROM TO BE COL 4 BELOW MINM SUPPLY IN DY
PIPE FROM DISTRY:
BRICK BALLAST
1/2 x
y
x
CENTRE LINE OF WATER COURSE

TABLE OF DIMENSIONS.

(of Gibb's Module)

D	x	y	Height of Minm. Head work above Masonry Platform
Ounces.	Ft.	Ft.	Ft.
·1	·2	3	·4
·4			·45
·5			·50
·6		7·5	·55
·7			·60
·8			·65
·9	1·7		·70
1·0			·70
1·1			·75
1·2		1·00	·80
1·3			·80
1·4			·85
1·5			·90
1·6			·90
1·7			·95
1·8			·95
1·9	2·1	1·25	·95
2·0			·95
2·2			1·00
2·4			1·00
2·5			1·00
2·8			1·00
3·0			1·00
		1·50	
32·5	3·0		1·00
3·5			1·00
37·5	3·4		1·00
4·0			1·00
4·5	3·8		1·00
5·0	4·25		1·00
		1·75	
5·5	4·7		1·00
6·0	5·1		1·00

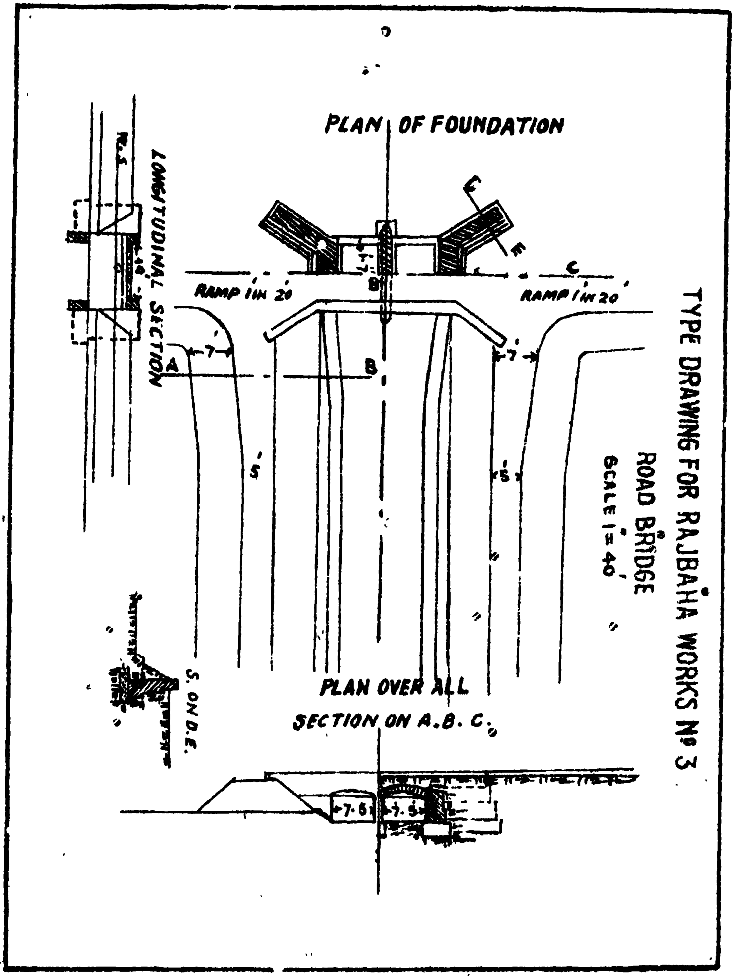

FIG 2.

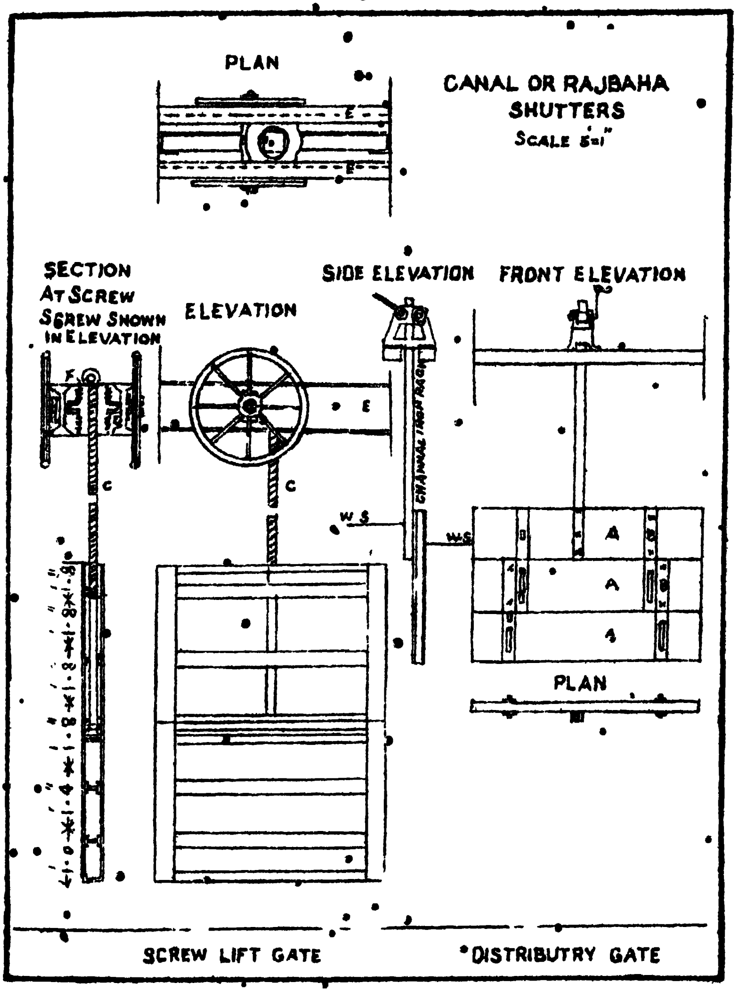

FIG 1.

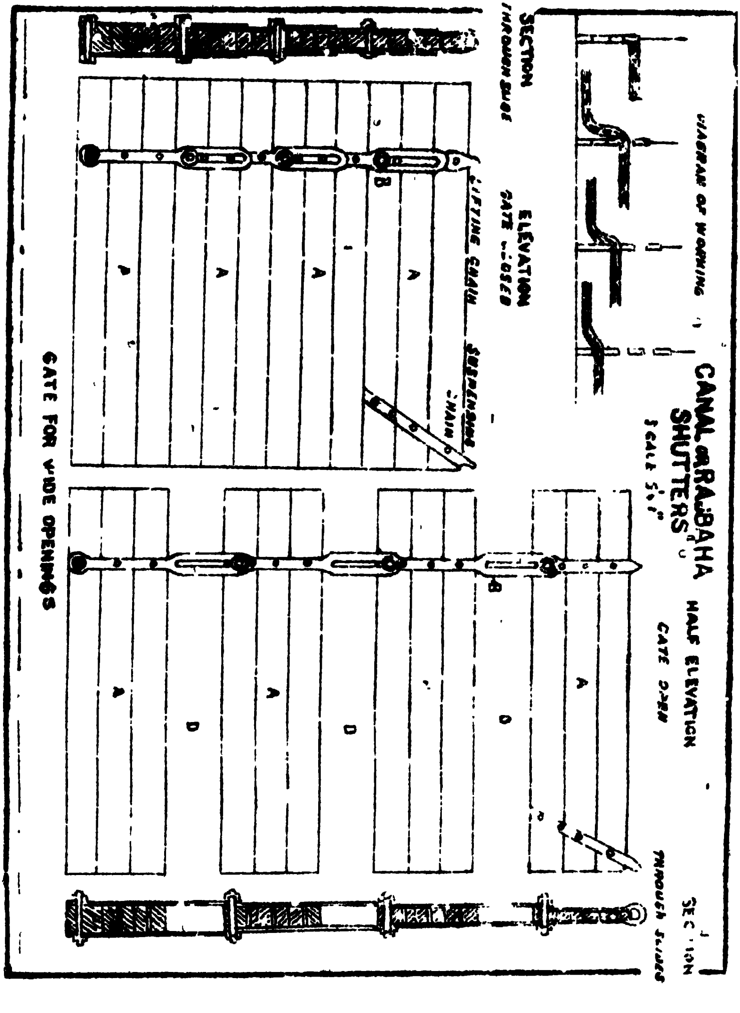
NOTE.—These dimensions are for modules in which angle irons are placed on the sides as in Fig. 1.

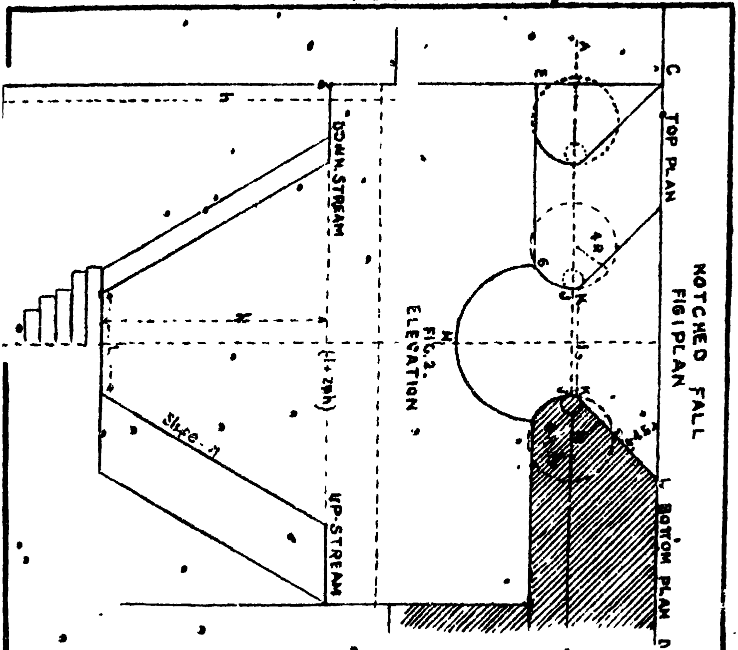
But for those on which the angle irons are below as in Fig. 2, the extra depth of angle iron should be allowed for.

N.B.—In cases where x does not work out to even half bricks the nearest greater thickness of wall in even half bricks should be used.

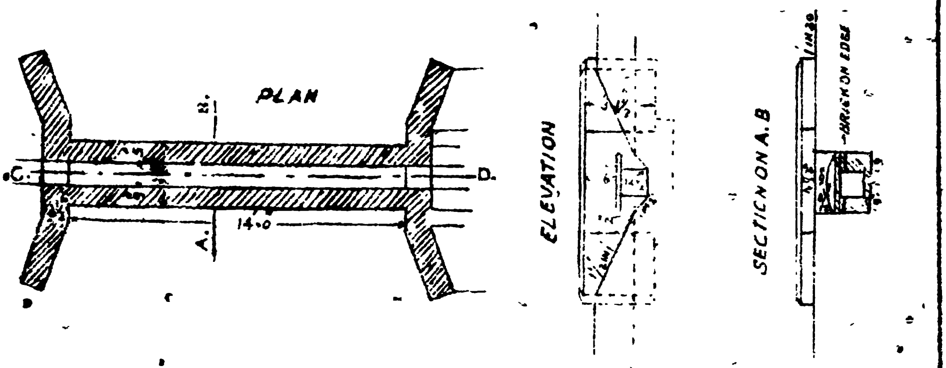

TYPE DRAWING FOR RAJBAHA WORKS No 3
ROAD BRIDGE
SCALE 1" = 40'
PLAN OF FOUNDATION
RAMP 1 IN 20
RAMP 1 IN 20
LONGITUDINAL SECTION
S. ON D.E.
PLAN OVER ALL
SECTION ON A.B.C.

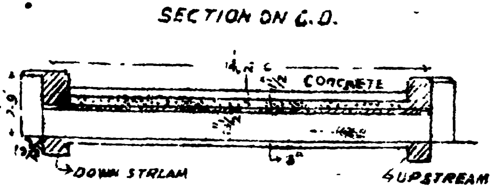

PLAN
CANAL OR RAJBAHA
SHUTTERS
SCALE 5'=1"
SECTION
AT SCREW
SCREW SHOWN
IN ELEVATION
ELEVATION
SIDE ELEVATION
FRONT ELEVATION
CHANNAL IRON RAGS
W.S
W.S
A
A
PLAN
SCREW LIFT GATE
DISTRIBUTRY GATE


CANAL RAJBAHA SHUTTERS
DIAGRAM OF WORKING
SECTION THROUGH SLUICE
ELEVATION GATE CLOSED
LIFTING CHAIN
SUSPENDING CHAIN
HALF ELEVATION
GATE OPEN
GATE FOR WIDE OPENINGS



Note.— A B. is the horizontal trace of the calculated vertical plane C. D. that of the upstream face of the notch wall. F. F! that of the downstream face, The thickness, from C. D. to A. B. is rather more than double that from E. F. to A. B. which latter varies from 6″ in small notches to 18″ in large ones. The arcs I. J. and G. J. are each of 45°. The arcs J. K. and J́. Ḱ. are also of 45° each but with ¼ radius. K. L is tangent to smaller circles meets C. D. at 45° and is the horizontal trace of the upstream face plane inclined to the vertical also sloping back from C. D. G. H. I.—the lip of the fall—is semicircular, Hh=estimated full supply depth.





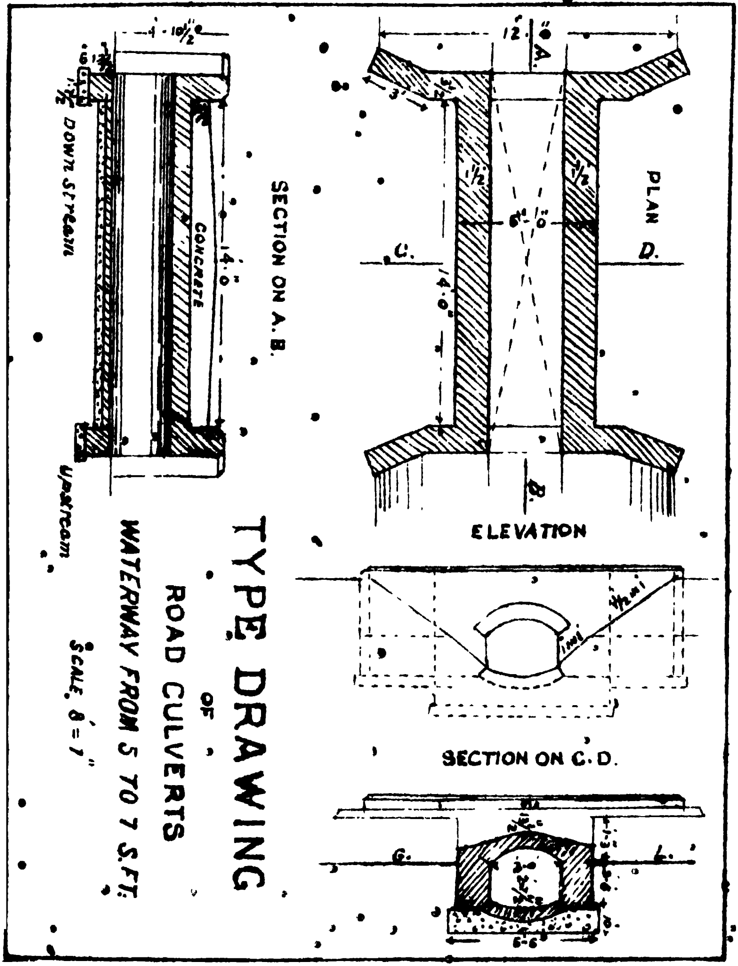
TYPE DRAWING

OF

ROAD CULVERTS

WATERWAY FROM 1 TO 4 S.FT.

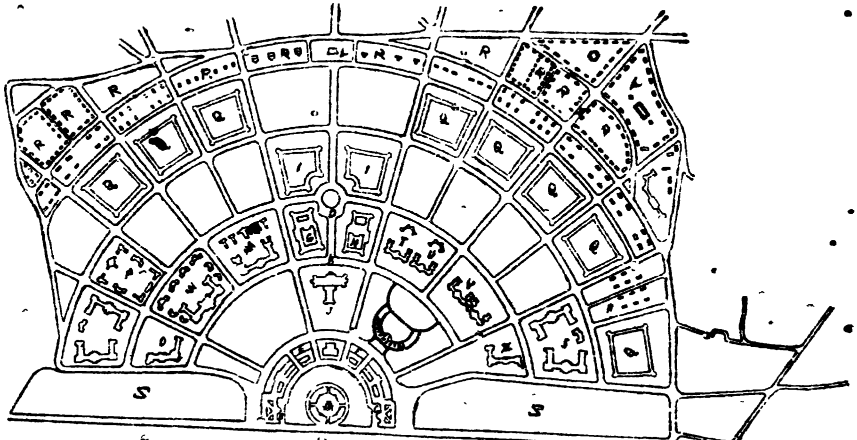
SCALE 8' = 1"



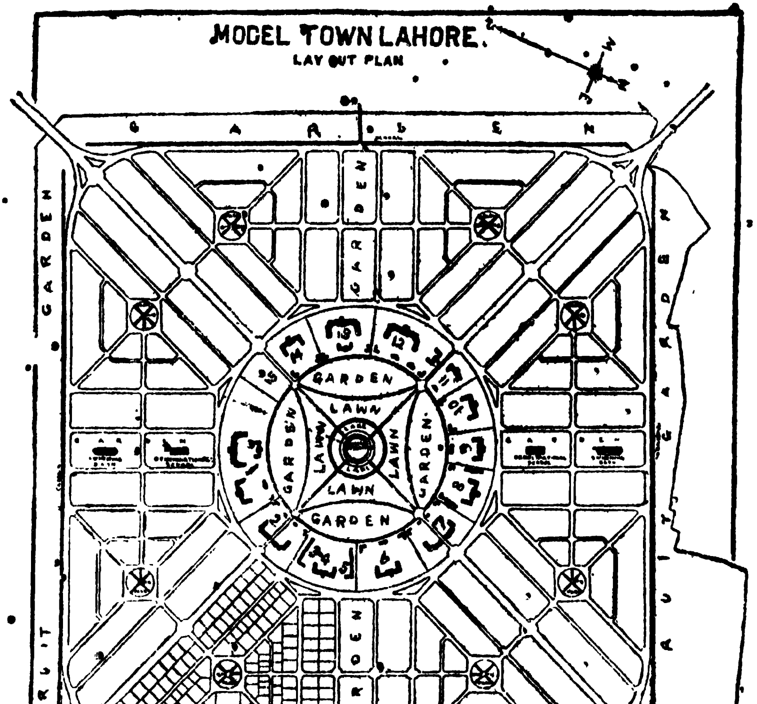
TYPE DRAWING
OF
ROAD CULVERTS
WATERWAY FROM 5 TO 7 S.FT.
SCALE, 8′ = 1″
SECTION ON A.B.
CONCRETE
DOWN STREAM
UPSTREAM
PLAN
ELEVATION
SECTION ON C.D.
14′.0″
6′-0″
12′-6″

BENARES HINDU UNIVERSITY

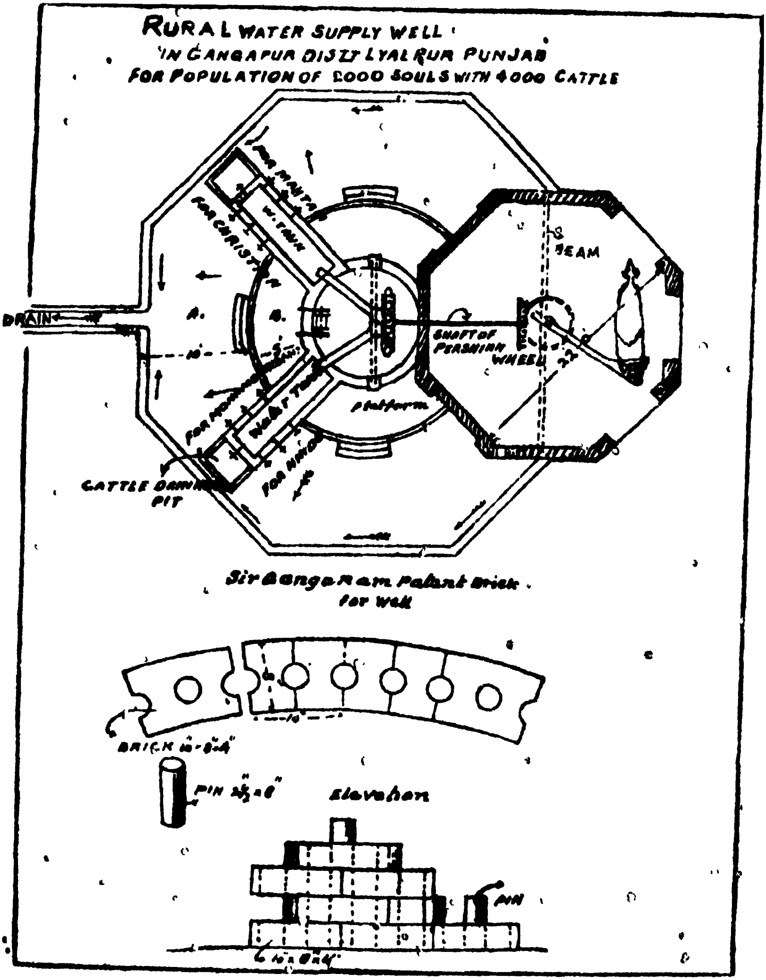
LAY OUT PLAN



A. Temple
B. Oriental Learning
C. Theology
D. Observatory
E. Art Gallery
F. Fine Arts
G. Sanskrit Library
H. General Library
I. Museum
J. Senate Hall
K. Clock Tower
L. Vice Chancellor's Lodge
M. Engineering College, Power House, University Press
N. Biology
O. Agricultural & Veterinary College
P. Hand Loom Factories
Q. Hostels
R. Residences.
S. Hospital
T. Chemical Laboratory
U. Physical Laboratory
V. Arts College & Law also to be used as Training College
W. Technical institute
X. Cooperative Stores & Shops
Y. Vanprastha Ashram
Z. Botanical Garden



1. Boy's School
2. Stores & Market
3. Police & Fire Station
4. Bank
5. Post & Telegraph Office
6. Gentlemen's Club (1)
7. Townhall & Library
8. Hotel & Baratghar
9. Places of Amusement
10. Ladies Club
11. Children's Nursery
12. Girl's School
13. Hospital
14. Gentlemen's Club (2)
15. Unforeseen
16. Places of Worship (3)
17. Local Shops 24 blocks)
18. Reservoir for Water Supply


RURAL WATER SUPPLY WELL
IN GANGAPUR DISTT LYALPUR PUNJAB
FOR POPULATION OF 2000 SOULS WITH 4000 CATTLE
DRAIN
BEAM
SHAFT OF PERSHIAN WHEEL
Platform
CATTLE DRINKING PIT
Sir Ganga Ram Patent Brick
for Well
Elevation
PIN

INDEX

INDEX TO PART I.—(Text.)

INDEX.

INDEX TO PART II.—(Drawings).

END

ERRATA.

Page 1.—Col. 2 line 37, *for* 8,466 *read* 7,466.
Page 1.—Col. 3, line 18, *for* 4,390,000 *read* 4,390,219.
Page 2.—Col. 5, line 10, *for* 163,638 *read* 163,838.
Page 3.—Col. 4, line 17, *for* 40,429 *read* 40,229.
Page 3.—Col. 4, line 18, *for* 553,051 *read* 553,651.
Page 3.—Col. 7, line 5, *for* ·0 *read* 0·4.
Page 10.—Col. 4, line 4, *for* 17·420 *read* 7·420.
Page 10.—Col. 9, line 7, *for* 1·493 *read* 0·493.
Page 20.—Col. 1, line 4, *below* ¾ *read* 1.
Page 22.—Col. 1, line 5, *for* 8¼ *read* 18¼.
Page 35.—Col. 7, line 40, *for* 100001 *read* 1000000.
Page 57.—Line 2, *for* 'weight of metal' *read* 'weight of iron'.
Page 57.—Line 10, *for* $(4+4) \times \frac{1}{2} = (\frac{1}{2})^2$ *read* $(4+4) \times \frac{1}{2} - (\frac{1}{2})^2$.
Page [illegible].—Line 34, *for* 'wieght' *read* 'weight'.

Page 86.—Line [illegible], *for* $l = \frac{K}{5^2}$ *read* $l = \frac{K}{S^2}$

Page 103.—Col. 7, line 3, *for* Breaking sprain *read* Breaking Strains.
Page 106.—Line 26, *for* Depth of head=45D *read* Depth of head=·45D.
Page 106.—Line 27, *for* Diameter of head=45D *read* Diameter of head=1·5D.
Page 112.—Line 9, *for* placed thus ⊥ *read* placed thus T.
Page 112.—Line 19, *for* ½″ thick instead of ⅜″ *read* ⅜″ thick instead of ½″.

Page 121.—Line 16, *for* $W = \frac{44{\cdot}34\ L^{3\cdot55} - d^{3\cdot55}}{L^{1\cdot7}}$ *read* $W = 44{\cdot}34\ \frac{D^{3\cdot55} - d^{3\cdot55}}{L^{1\cdot7}}$

Page 122.—Col. 9, line 11, *for* 98840 *read* 68840.

Page 124.—Lines 9 and 12, *for* $P = \frac{S \times C}{1 + a\frac{L}{d^2}}$ *read* $P = \frac{S \times C}{1 + a\frac{L^2}{d^2}}$

Page 126.—Line 44, *for* $17^3 \sqrt{(L + {\cdot}00012\ v^2)^2}$ *read* $17\sqrt[3]{(L + {\cdot}0001\ L\ v^2)^2}$.
Page 129.—Line 1, *for* Heigh *read* Height.
Page 137.—Line 15, *for* 'by 333½' *read* 'by 333⅓.'
Page 137.—Line 18, *for* $896 \times 102\frac{6}{7}$ *read* $896 \times 142\frac{6}{7}$.
Page 137.—Line 23, *for* 6843000 *read* 68430000.
Page 138.—Line 8, *for* 'multiply 33,333 etc' *read* 'multiply by 33,333 etc.

Page 140.—Line 2, *for* $a = \frac{d}{\sqrt{}}$ *read* $a = \frac{d}{\sqrt{2}}$

Page 140.—Line 11, *for* '$2\angle\Delta$' *read* $\frac{2\Delta}{c}$

Page 140.—Line 17, *for* $\frac{b}{4}\sqrt{2 - b^2}$ *read* $\frac{b}{4}\sqrt{4a^2 - b^2}$

Page 156.—Line 29, *for* $\log a\frac{m}{n} = \log_a m - \log_a$ *read* $\log a\frac{m}{n} = \log a\ m - \log a\ n$.

Page 157.—Line 3, *for* characteristics-1 *read* characteristic is -1.
Page 157.—Line 19, *for* value of $(20\cdot3^5)$ *read* value of $(20\cdot3)^5$.
Page 157.—Line 21, *for* $(20\cdot3) = 3447000$ *read* $\therefore (20\cdot3)^5 = 3447460$.
Page 160.—Line 3, *for* log. $\cdot315 = \bar{1}\cdot49831$ *read* log $\cdot315 = \bar{1}.49831$.
Page 164.—Line 13, *for* angles of equal area *read* triangles of equal area.
Page 165.—Line 13, *for* lay off n ay points *read* lay off any points.
Page 172.—Line 12, *for* the distace. n *read* the distance.
Page 173.—Line 6, *for* draw *am read* draw *an*.
Page 173.—Line 18, *for* Subtractc *read* Subtract *e*.
Page 174.—Line 18, *for* Earthware *read* Earthwork.
Page 177.—Line 28, *for* lengths alon *read* lengths alone.

Page 192.—Line 9, *for* 804 for 20 *read* 804 for 32.
Page 209.—Line 24, *for* two per each 12 hours *read* one per each 12 hours
Page 210.—Line 23, *for* pred *read* spread.
Page 212.—Line 29, *for* platered *read* plastered.
Page 227.—Line 42, *for* heat *read* beat.

Page 230.—Line 28, *for* $3 \times 2\frac{1}{1} = 6\cdot19$ *read* $3 \times 2\frac{1}{10} = 6\cdot19$.

Page 232.—Line 13, *for* (see sketch above) *read* (see sketch below).

Page 233.—Line 2, *for* $\frac{15\cdot7}{2} = 4$ ft. *read* $\frac{15-7}{2} = 4$ ft.

Page 278.—Line 1, *for* 167 sq. inches *read* 1·67 sq. inches.
Page 298.—Lines 13, 21 and 22, *for* number *read* member.
Page 315.—Line 4, *for* dia grams *read* Drawings.

Page 324.—Line 2, *for* $\frac{7\cdot7 \times 1\cdot5}{2} \times 28$ *read* $\frac{7\cdot7 + 1\cdot5}{2} \times 28$.

Page 328.—Line 17, *for* hearth *read* earth.
Page 333.—Line 20, *for* florr *read* floor.
Page 394.—Line 15, *for* hall *read* shall.
Page 426.—Line 45, *for* leaat *read* least.
Page 448.—Col. 2, line 3, *for* onal *read* canal.
Page 448.—Line 15, *for* cause *read* cusec.
Page 495.—Line 24, *for* 3″ pipe *read* 8″ pipe.
Page 563.—Line 11, *for* incarees *read* increases.